VOLUME XLVIII NUMBER 4

BOTANICAL GAZETTE

OCTOBER 1909

THE EMBRYO SAC OF HABENARIA[1]

WILLIAM H. BROWN

(WITH TWELVE FIGURES)

The present investigation was made on *Habenaria ciliaris* (Michx.) R. Br. and *H. integra* (Nutt.) Spreng. The development of the two species is very much alike and the same description will apply to both. The material was fixed in medium chromacetic and the sections were

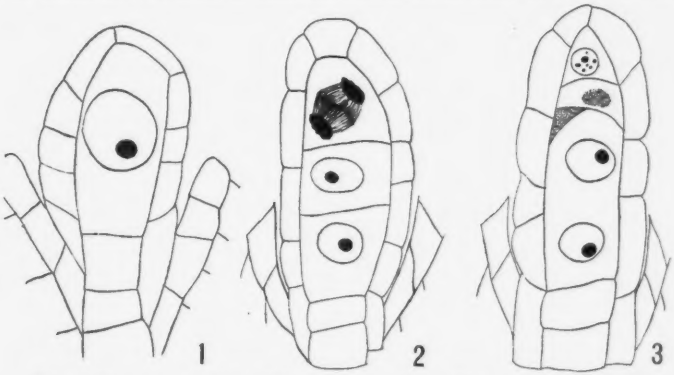


FIG. 1. Megaspore mother cell in apex of nucellus.—FIG. 2. Megaspores.—FIG. 3. First division of functional megaspore and three degenerating megaspores.

cut 10 μ thick and stained with Flemming's triple or Haidenhain's iron alum hematoxylin.

The ovule of Habenaria is anatropous and has two integuments. The archesporium differentiates in the apex of the nucellus as a single hypodermal cell (*fig. 1*), which is the terminal cell of a row surrounded

[1] Contribution from the Botanical Laboratory of the Johns Hopkins University, No. 10.

only by the epidermal layer. The archesporial cell without dividing functions as a megaspore mother cell, which divides to two daughter cells, which in turn divide to form four megaspores. The last division may be simultaneous in both daughter cells, but usually it is delayed in the one nearest the micropyle (*fig. 2*).

Soon after the formation of the megaspores the chalazal one begins to enlarge at the expense of the other three, which soon degenerate. Before this degeneration has proceeded far the nucleus of the functioning megaspore divides (*fig. 3*) and the two daughter nuclei remain

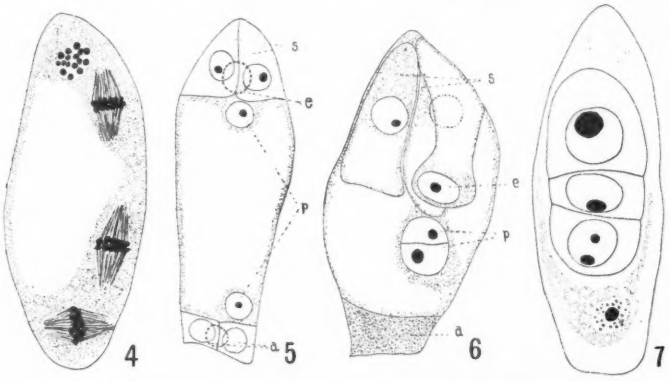
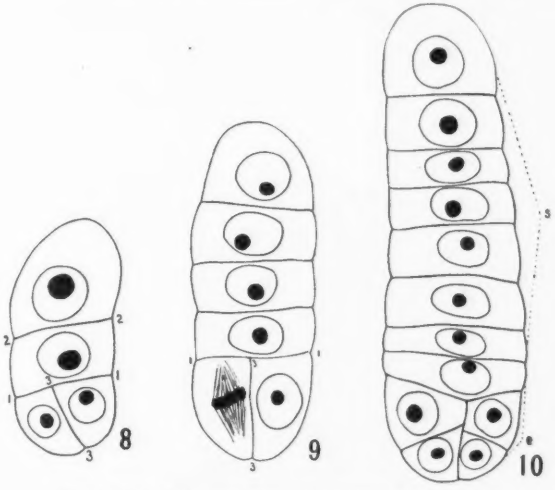


FIG. 4. Nuclei of four-nucleate embryo sac dividing to eight.—FIG. 5. Eight-nucleate embryo sac: *s*, synergids; *e*, egg; *a*, antipodals; *p*, polar nuclei.—FIG. 6. Embryo sac with fusing polar nuclei; *p*, polar nuclei; *s*, synergids; *e*, egg; *a*, degenerating antipodals.—FIG. 7. Young embryo and degenerating endosperm nucleus.

in the polar positions in the enlarging sac. Each of these two nuclei by two successive divisions gives rise to four, so that the mature sac contains eight nuclei (*fig. 5*). As the sac continues to enlarge, the nucellar cells which surrounded the four megaspores degenerate, so that at about the four-nucleate stage the sac comes to lie against the inner integument. At the last division of the embryo sac nuclei the two spindles in each end are arranged approximately at right angles to one another (*fig. 4*). As is usual, the transverse spindle in the micropylar end gives rise to two synergids, while the longitudinal one forms the egg and the micropylar polar nucleus. In the chalazal end the longitudinal spindle gives rise to the antipodal polar nucleus and one

antipodal, while the other spindle forms two antipodals. Walls cutting off the egg, synergids, and antipodals are formed on fibers connecting the nuclei. Owing to their position nearer the center of the sac, the polar nuclei are left free in the cytoplasm (*fig. 5*), as has been pointed out by STRASBURGER ('05) for *Drimys Winteri*. After their formation, the egg and synergids enlarge considerably, while the antipodals soon degenerate (*fig. 6*). When the egg and synergids have about reached their mature size, the polar nuclei fuse (*fig. 6*). No cases were observed in which the polar nuclei were in con-



FIGS. 8–10. Older embryos: *s*, suspensor; *e*, embryo.

tact without fusing, as have been described for other forms by STRASBURGER ('00) and NAWASCHIN ('00). The pollen tube comes through the micropyle and discharges the two male nuclei into the embryo sac. One of these fuses with the egg, while the other fuses with the product of the fusion of the polar nuclei to form the primary endosperm nucleus. This enlarges somewhat, but without dividing begins to degenerate at about the time of the first division of the fertilized egg (*fig. 7*).

The first division of the fertilized egg is transverse to the longitudinal axis of the embryo sac. Of the two resulting cells the chalazal one

forms most of the embryo, while the micropylar one gives rise to the suspensor and a small part of the young embryo. The second division (*fig. 8, wall 2*) is in the micropylar cell and is also transverse; the third division (*fig. 8, wall 3*) is in the chalazal cell and is longitudinal. Divisions continue in the descendants of the micropylar cell until a row of about eight cells is formed (*fig. 10*). The seven of these which are nearest the micropyle make up the suspensor, while later on the other one divides to form part of the embryo (*fig. 11*). The first division in this cell may be either transverse or longitudinal. When the row of cells derived from the primary micropylar cell has become four or more cells long, transverse segmentation begins in the descendants of the chalazal cell (*fig. 9*), so that this becomes cut into quadrants (*fig. 10*). Up to this stage the embryo and suspensor have remained within the embryo sac cavity, but now the cells of the suspensor elongate and the free end of the suspensor is pushed through the micropyle out beyond the integuments (cf. shape of cells in *figs. 10* and *11*). The cells of the embryo undergo further division and form a globular mass; *fig. 12* represents a young embryo in which *walls 1* and *3* correspond to *1* and *3* of *figs. 8–11*.

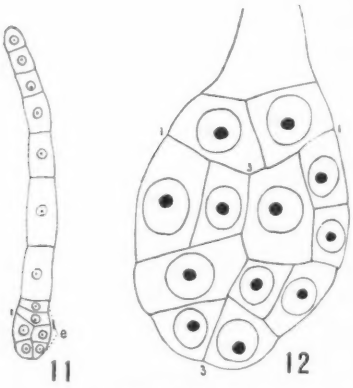


FIG. 11. Still older embryo drawn on a smaller scale; the suspensor has elongated. —FIG. 12. Many-celled embryo.

Discussion

MEGASPORES

In Habenaria the megaspore mother cell divides to two daughter cells and each of these divides to two megaspores. The division in the daughter cell nearest the micropyle is usually delayed until after that in the daughter cell nearest the chalazal end. If this delay was carried a little farther, we should have the condition described in

several other orchids (WARD '80, STRASBURGER '84), which have only three megaspores.

In Cypripedium (PACE '08) the daughter cells of the megaspore mother cell do not divide, but one of them forms the embryo sac. In this case the question arises as to whether the division of both daughter cells has been omitted, in the way indicated for one of them in Habenaria, and the place of the second "reducing division" changed to the embryo sac mother cell (the cell within the walls of which the embryo sac is organized); or whether the first two nuclei of the embryo sac are, as Miss PACE calls them, megaspore nuclei. In favor of the latter view it may be said that the "completion of chromosome reduction" which takes place in the division of the daughter cell is necessary to the normal development of the embryo sac. COULTER ('08) thinks that because chromosome reduction, which is usually associated with megaspore formation, is necessary that megaspore nuclei cannot be omitted. On the other hand, the place of reduction is not always constant, even in nearly related plants, as in the case of Nemalion (WOLFE '04) and Polysiphonia (YAMANOUCHI '05). In Nemalion the fertilized egg divides to carpospores and, according to WOLFE, reduction takes place in their formation. In Polysiphonia reduction does not take place in carpospore formation, but the carpospore germinates to a plant with the diploid number of chromosomes. This plant bears not carpospores but tetraspores, and reduction takes place in the division of the tetraspore mother cell. In speaking of Polysiphonia, YAMANOUCHI says: "The tetrasporic plants may have arisen by a suppression of the reduction phenomena in connection with the carpospore, so that it germinates with the sporophytic number of chromosomes. . . . . The period of chromosome reduction would be thus postponed from the carpospore to a later period in connection with the newly formed plant." If, as seems probable, the place of reduction has been changed among the red algae, it is reasonable to suppose that it may also have been changed in some angiosperms, and especially if the structure in which it normally occurred had been left out of the life-history of the plant. The leaving-out of the division of the the mother cell into megaspores would simply be the completion of a tendency toward the reduction in the number of divisions of the archesporial cells from the condition in the ferns (where it divides a number

of times) to such a condition as Habenaria where the archesporial cell without dividing functions as a spore mother cell.

The only way in which we can claim that megaspore nuclei must accompany chromosome reduction is by defining a spore mother cell as that cell in which reduction is initiated and spore nuclei as the nuclei resulting from the reducing divisions. The logical conclusion of this would be to make chromosome behavior the sole criterion for distinguishing spores, sporophytes, and gametophytes; but since the four megaspores and embryo sac of Alchemilla (MURBECK '01) may have the diploid number of chromosomes, or the apogamous embryos of Nephrodium (YAMANOUCHI '08) the haploid number of chromosomes, we cannot regard chromosome behavior as the sole, if indeed the most important, criterion for distinguishing any of these structures.

A distinction between the first division of the megaspore and a division giving rise to megaspores is that while in the first case no cell plate is formed on the spindle, in the latter case either a wall or a cell plate is formed on the spindle. This wall may be formed in the embryo sac when this is derived from more than one megaspore, as is apparently the case in Peperomia (BROWN '08). The first division of the embryo sac mother cell nucleus of Cypripedium (PACE '08) agrees with that of those derived from one megaspore in having no cell plate formed on the spindle.

The evidence for either view is inconclusive, but seems to the writer to be in favor of the idea that in Cypripedium the second division in megaspore formation has been left out, and the place where "reduction is completed" changed to the first division of the nucleus of the embryo sac mother cell.

LLOYD ('02) and COULTER ('08) have advanced the idea that when megaspores are not formed the first four nuclei of the embryo sac are megaspore nuclei. This is probably true in such cases as Lilium (COULTER and CHAMBERLAIN '03) and Peperomia (BROWN '08), and as COULTER ('08) suggests in some other sixteen-nucleate embryo sacs; but if the ideas brought forward here concerning Cypripedium are correct, it need not be of universal application. CAMPBELL ('09), however, seems to think that even the embryo sacs of Lilium and Peperomia are not derived from more than one megaspore.

In discussing the view of COULTER ('08) that when the megaspore

mother cell does not divide the first four nuclei of the embryo sac are megaspore nuclei, and of BROWN ('08) that the embryo sac of Peperomia is composed of the descendants of four megaspores, CAMPBELL ('09) says: "The generally accepted view that in such cases as Peperomia and Lilium the embryo sac is a single megaspore formed without previous division from the mother cell can hardly be admitted to have been disproved by these recent speculations." In speaking of Peperomia, he says that BROWN bases his opinion that the first four nuclei of the embryo sac represent megaspores upon the fact that cell walls are formed in the first two nuclear divisions in *Peperomia sintensii* and cell plates in the same divisions in *P. pellucida;* while in the third division cell plates are wanting. CAMPBELL says that since in the last division, which gives rise to sixteen nuclei, cell walls are formed, "this seems rather inadequate grounds for assuming that the embryo sac represents four spores rather than a single one." The presence of the cell walls was not the only reason for thinking that the embryo sac of Peperomia represents four spores; but even if it were, the formation of walls in the last division would offer no difficulty to such a view, for walls are usually formed at the last division of the embryo sac of angiosperms and the writer has not been able to find any essential difference between the method of their formation in Peperomia and in Habenaria. Nor would the reduction of the free divisions in the embryo sac to a single one (the third in Peperomia) be a difficulty when we remember that the number of these is often large but quite variable in the gymnosperms and has been reduced to two in the ordinary angiosperms. The fact remains that unless we assume that the first four nuclei of the embryo sac of Peperomia and Lilium are megaspore nuclei, we have no explanation for the presence of walls in the first two divisions of the embryo sac of Peperomia and for the absence of these walls in the third division, or for the presence of cell plates on the spindles of the first two divisions of Lilium, features which have been described in no case, so far as the writer knows, in which the embryo sac is formed from one of four megaspores.

CAMPBELL thinks that if the compound nature of the sac of Lilium be admitted, we still have to explain the extraordinary departure of Peperomia from the usual type, but why two such distantly related plants would be expected to behave alike is not explained.

It does not seem likely that a primitive embryo sac, as CAMPBELL believes the sixteen-nucleate type to be, has been retained in plants so far examined only in such distantly related genera as Peperomia, Pandanus (CAMPBELL '09), Gunnera (ERNST '08), Euphorbia (MODILEWSKI '09), and the Penaeaceae (STEPHENS '08); and especially since most of these genera are anything but primitive in other respects, and the embryo sac is in most cases derived from a spore mother cell which, as CAMPBELL says, can hardly be regarded as a primitive feature.

ENDOSPERM

NAWASCHIN ('00) finds that in Phajus and Arundina there is no fusion of the polar or second male nuclei, and he attributes the lack of endosperm to this cause. STRASBURGER ('00) has shown that in several European orchids this fusion may or may not take place, but in either case there is no division to form endosperm. He concludes from this that the lack of endosperm is not due to the failure of the nuclei to fuse. The condition in Habenaria, where there is no endosperm, although the fusion nucleus is of constant occurrence, is a confirmation of this view.

In contrast to Habenaria, endosperm may be formed in Lemna (CALDWELL '99) without a fusion of the polar nuclei.

In the aposporous embryo sac of Hieracium (ROSENBERG '06) polar nuclei with the diploid number of chromosomes may fuse to form the endosperm nucleus. In all known sixteen-nucleate sacs all of the nuclei not cut off by walls fuse to form the primary endosperm nucleus. In *Peperomia hispidula* (JOHNSON '07) there are fourteen of these fusing nuclei; while in *P. pellucida* (JOHNSON '00) and *P. sintensii* (BROWN '08) there are eight; in the Penaeaceae (STEPHENS '08) and *Euphorbia procera* (MODILEWSKI '09) there are four; and in Gunnera (ERNST '09) seven.

The fact that in Habenaria the fusion of the polar and second male nuclei does not result in the formation of endosperm, while in Lemna endosperm is formed without this fusion, taken together with the fact that the primary endosperm nucleus may be formed by the fusion of a variable number of nuclei or of nuclei with either the diploid or haploid number of chromosomes, seems to strengthen STRASBURGER'S ('05) view that the endosperm is not a sexually produced embryo, but

that the fusion of the nuclei is connected with the fact that the nuclei have ceased developing and are in the same cell cavity.

Summary

The archesporium of Habenaria arises as a single hypodermal cell, which without dividing functions as a megaspore mother cell.

The mother cell divides to two daughter cells and each of these to two megaspores. The division of the daughter cell nearest the micropyle is usually delayed.

In some cases an embryo sac is probably formed from more than one megaspore; but the condition in the orchids, where there is a gradual reduction of the divisions of the megaspore mother cell without an indication of walls in the embryo sac, indicates that megaspore formation may be omitted and the place of reduction changed to the first division of the nucleus of the embryo sac mother cell.

The embryo sac of Habenaria contains eight nuclei: an egg, two synergids, two polar nuclei, and three ephemeral antipodals.

The primary endosperm nucleus is formed by the fusion of the polar and second male nuclei, but degenerates without dividing.

The absence of endosperm in many orchids offers no support to the view that the endosperm is a sexually produced embryo.

The fertilized egg gives rise to a long suspensor and a globular embryo.

My thanks are due to Professor D. S. JOHNSON for helpful suggestions and criticisms.

JOHNS HOPKINS UNIVERSITY
Baltimore, Maryland

LITERATURE CITED

1. BROWN, W. H., The nature of the embryo sac of Peperomia. BOT. GAZETTE **46**:445–460. *pls. 31–33.* 1908.
2. CALDWELL, O. W., On the life-history of *Lemna minor.* BOT. GAZETTE **27**:37–66. *figs. 59.* 1899.
3. CAMPBELL, D. H., The embryo sac of Pandanus. Bull. Torr. Bot. Club **36**:205–220. *pls. 16, 17.* 1909.
4. COULTER AND CHAMBERLAIN, Morphology of angiosperms 80. 1903.

5. COULTER, J. M., Relation of megaspores to embryo sacs in angiosperms. BOT. GAZETTE **45**:361–366. 1908.
6. ERNST, A., Zur Phylogenie des Embryosackes der Angiospermen. Ber. Deutsch. Bot. Gesells. **26**:419–437. *pl. 7.* 1908.
7. JOHNSON, D. S., On the endosperm and embryo of *Peperomia pellucida*. BOT. GAZETTE **30**:1–11. *pl. 1.* 1900.
8. ———, A new type of embryo sac in Peperomia. Johns Hopkins University Circular 195:19–21. *pls. 5, 6.* 1907.
9. LLOYD, F. E., The comparative embryology of the Rubiaceae. Mem. Torr. Bot. Club **8**:27–112. *pls. 8–15.* 1902.
10. MODILEWSKI, J., Zur Embryobildung von *Euphorbia procera*. Ber. Deutsch. Bot. Gesells. **27**:21–26. *pl. 1.* 1909.
11. MURBECK, S., Parthenogenetische Embryobildung in der Gattung Alchemilla. Lunds Univ. Arsskrift **362**: No. 7, 46. *pls. 6.* 1901.
12. NAWASCHIN, S., Ueber die Befruchtungsvorgänge bei einigen Dicotyledoneen. Ber. Deutsch. Bot. Gesells. **18**:224–230. *pl. 9.* 1900.
13. PACE, LULA, Fertilization in Cypripedium. BOT. GAZETTE **44**:353–374. *pls. 24–27.* 1908.
14. ROSENBERG, O., Ueber die Embryobildung in der Gattung Hieracium. Ber. Deutsch. Bot. Gesells. **24**:157–161. *pl. 11.* 1906.
15. STRASBURGER, E., Einige Bemerkungen zur Frage nach der "doppelten Befruchtung" bei den Angiospermen. Bot. Zeit. **58**:293–316. 1900.
16. ———, Die Samenlage von *Drimys Winteri* und die Endospermbildung bei Angiospermen. Flora **95**:215–231. 1905.
17. STEPHENS, E. L., A preliminary note on the embryo sac of certain Penaeaceae. Annals of Botany **22**:329. 1908.
18. WARD, H. MARSHALL, On the embryo sac and development of *Gymnadenia conopsea*. Quart. Jour. Micr. Sci. **20**:1–18. *pls. 1–3.* 1880.
19. WOLFE, J. J., Cytological studies in Nemalion. Annals of Botany **18**:608. 1904.
20. YAMANOUCHI, S., The life-history of *Polysiphonia violacea*. BOT. GAZETTE **42**:401–449. *pls. 19–28.* 1906.
21. ———, Apogamy in Nephrodium. BOT. GAZETTE **45**:289–318. *pls. 9, 10.* 1908.

THE INFLUENCE OF TRACTION ON THE FORMATION OF MECHANICAL TISSUE IN STEMS[1]

JOHN S. BORDNER

Introduction

The following investigation was directed to a further knowledge of the influence of traction in the direction of the longitudinal axis on the formation of mechanical tissue in the stems of plants.

Petioles, tendrils, and roots were not investigated, because the wo k of HEGLER (**9**), BALL (**1**), and HIBBARD (**11**) was primarily on stems, and it was my purpose to add further and more detailed experimental evidence to the work done by these investigators.

This research was carried on in the Botanical Labo atory of the University of Michigan. It was under the direction of Prof. F. C. NEWCOMBE, to whom I am indebted for encouragement and helpful suggestions. I wish, also, to express my appreciation of the interest manifested in my work by the other members of the staff in the botanical department.

Historical

I. STEMS: INFLUENCE OF TRACTION

BARANETSKY (**2**) observed that a stem of *Gesneria tubiflora* weighted with 30^{gm} made less growth than one remaining free. SCHOLTZ (**26**) verified this observation of BARANETSKY, and found that stems when subjected to traction first grew more slowly and later more rapidly than the control plants. This he att ibuted to a change in the physical condition of the cell resulting from the educed hydrostatic pressure. He furnished no experimental evidence to support his theory. HEGLER (**9**) produced the first experimental evidence to show that plants respond to tension by an increased formation of mechanical tissue. This supported the theory which was generally adhered to by plant physiologists previous to that time; viz., that a plant reacts to a gradually increasing strain by an increased

Contribution No. 111 from the Botanical Department of the University of Michigan.

development of its mechanical tissue. In reporting the work of HEGLER, PFEFFER (**21**) says that a seedling of *Helianthus annuus*, whose original breaking strength was 160^{gm}, had a breaking strength of 250^{gm} after two days under the pull of 150^{gm}. No breaking strength is given for a control. A petiole of *Helleborus niger* which withstood a weight of only 400^{gm}, PFEFFER reports to have held a weight of 3.5^{kg} after 5 days, during which time it had been weighted with a gradually increasing load, while similar petioles under normal conditions gained but little in strength. Changes are also reported in the anatomical structure: (1) an increase in the number of cells of the collenchyma, (2) an increased thickness of the walls of the collenchyma, sclerenchyma, and bast, and (3) the production of entirely new tissues. It is unfortunate that a full account of HEGLER'S methods and work was not published.

HEGLER (**10**) showed that the phenomenon observed by BARANETSKY and SCHOLTZ was not purely physical, but that a physiological change took place within the cell, due to stimulation coming from the tension. As evidence, he demonstrated that when plants were dep ived of oxygen or when they were under the influence of chloroform, there was no response. He also found that the plants under tension were more turgid than controls, instead of less as SCHOLTZ had claimed.

RICHTER (**25**) concluded that when the stems of Chara were subjected to a longitudinal pull, there was an increase in strength. BALL'S criticism of RICHTER'S work is well taken. He says: "Die Resultate RICHTER'S sind etwas zweifelhaft, da er keinen Vergleich zwischen belasteten Chara Pflanzen und unbelasteten von demselben Alter und derselben Grösse gegeben hat."

KÜSTER (**15**) found no response, and showed that in the petioles of *Helleborus niger* the new elements, which HEGLER (**91**) claimed were produced in response to tension, were there before tension was applied. PFEFFER (**22**, p. 148) also found no response in the production of mechanical tissue in plants subjected to tension.

VÖCHTING (**27**) investigated the influence of tension on sunflowers and cabbages that had been prevented from flowering by means of decapitation. He found that no new tissue was formed, and that no increase in mechanical tissue occurred as a result of tension.

WIDERSHEIM (**29**) experimented with pendant branches of Fraxinus, Fagus, Caragana, Sorbus, Ulmus, and Corylus. He fastened weights directly to these branches and continued the experiment through most of the growing season. Only in the case of Co-ylus was there any response; viz., an increase in the number of bast fibers.

BALL (**1**) experimented with *Helianthus annuus, Phaseolus multiflorus, Lupinus albus, Helleborus niger, Ricinus communis,* two species of Cyperus, and *Mirabilis jalapa.* His conclusion was that these plants do not respond to tension by an increase of their breaking strength or by the production of mechanical tissue.

HIBBARD (**11**) found an increase of mechanical tissue in the stem of *Vinca major* when the same was subjected to longitudinal pull. He failed to find any response in the stems of *Helianthus annuus, Ricinus communis, Brassica oleracea,* and *Phaseolus multiflorus.* HIBBARD did not determine the breaking strength of his stems.

2. STEMS: THE INFLUENCE OF COMPRESSION; ALSO COMPRESSION AND PULL COMBINED

KNIGHT (**14**) tied a young tree in such a manner that it was swayed only in the plane of the prevailing wind. After the lapse of one growing season, the diameter in this plane was found to be greater than the diameter at right angles to the same.

HIBBARD (**11**) found that compression caused a small increase of mechanical tissue in the stems of Fuchsia, Vinca, and Helianthus, while Coleus gave no response.

3. ROOTS: RESPONSE TO TENSION

HIBBARD (**11**) says: "Pull in the direction of the longitudinal axis of the plant called forth a small increase of mechanical tissue in the main and lateral roots of *Helianthus annuus* and *Ricinus communis.*"

4. TENDRILS AND PETIOLES

DARWIN (**4**; GRAY **8,** p. 176) says that in the grape-vine, Virginia creeper, etc., attached tendrils thicken and harden, gaining wonderfully in strength and durability, while those which remain unattached soon shrink up or wither and fall off.

MÜLLER (**18**) found that contact produced earlier and greater lignification of the sclerenchyma, even in the free portion of the ten-

drils of the Cucurbitaceae; but he did not consider tension as a probable factor along with contact.

WORGITZKY (**30**) reports that tendrils of *Passiflora quadrangularis* which had grasped a support broke at 600^{gm}, while the controls broke at 350^{gm}. With tendrils of Cucurbitaceae, the uncoiling resistance was thirteen times as great in those which had grasped a support. There was also a marked anatomical change; viz., a lignification of the pith parenchyma, which he assigned to no cause.

VON DERSCHAU (**28**) found that a gradually increasing pull on certain twining petioles raised their breaking strength and caused an increased development of mechanical tissue. He found a numerical increase in almost all kinds of cells. The petioles of *Solanum jasminoides* showed the least response.

NEWCOMBE (**19,** p. 446) says, in speaking of the reaction of tendrils to contact: "The first strengthening tissue is here laid down as a response to contact; its increase is the regulatory response of the plant to the strain that it feels."

MACDOUGAL (**17,** pp. 377, 378) believes that contact stimuli are not transmitted beyond 2 or 3^{mm}. Since the thickening of the tendril always takes place after contact, the natural conclusion would be that this thickening of the tendril is due to the traction exerted by the weight of the stem supported by it.

PEIRCE also (**20,** p. 241) believes that the strengthening of the free basal portion is not due to contact.

FITTING (**6,** p. 476) has demonstrated that contact stimuli are transmitted to the basal portion of the tendril, and that therefore the effect of contact stimuli on the basal portion of tendrils cannot be excluded.

5. CORRELATION

The factor of correlation has been investigated by numerous workers. Since self-regulatory development may imply a certain degree of correlation, it seems desirable that at least a brief review of the work on correlation should be given.

LABORIE (**16**) found decided differences in the anatomical structure of the floral axis compared with the rest of the plant: (1) an increase of bast, (2) a decided modification of the main bundles, and (3) a decrease of pith.

KLEIN (**13**) found the bundles more centrally located in the fruit stalk than in the petiole. He attributed this arrangement to the necessity for a greater mechanical strength, as well as for a more abundant supply of building material.

DENNERT (**5**) compared the anatomical structure of the fruit stalk before and after the ripening of the fruit. He found an increase in the development of mechanical tissue. There was an increased amount of xylem and a greater thickness of the walls of the wood fibers.

REICHE (**24**) investigated the transformation from flower to fruit stalk in many additional plants. His conclusions agree with those of the earlier investigators.

PIETERS (**23**) showed that one-year-old fruit-bearing shoots of the apple and the pear had a smaller xylem cylinder in proportion to their diameters than the vegetative shoots of same age. They were well supplied with supplementary mechanical tissue, however, which was distributed at those points where it was most needed. In the case of the peach and the plum, the woody cylinder of the fruit-bearing shoot was larger than in the vegetative shoot. There was an abundance of well-lignified sclerenchyma and hard bast in the fruit-bearing shoots of the apple and pear, while in the vegetative shoots these tissues appeared only sparingly, if at all.

GOEBEL (**7**, p. 206) writes: "Careful research demonstrates the existence of reciprocity between parts of the plant body. . . . . The size and construction of one organ are frequently determined by those of another."

BOODLE (**3**) states that the walls of the sieve tubes and companion cells in *Helianthus annuus* become lignified as a result of strain. He also found a slight lignification of the parenchymatous parts of the pericycle and medullary rays, thus uniting the primary sclerenchyma strands into a more definite mechanical system attached to the strong xylem by the medullary rays. He says: "This must give greater rigidity, which no doubt is required by the heavy fruiting capitula borne by the plants."

KELLER (**12**) reached conclusions directly opposed to those reached by BOODLE. He showed that a strong or light pull in the direction of the longitudinal axis of orthotropic flower stalks exerted

no influence on the development of mechanical tissue. The displacement of orthotropic flower shoots to a plagiotropic position, he claimed, caused a certain anatomical change. This he attributed to the change in position and not to tension. His conclusion does not agree with those of other investigators, viz., that mechanical development of the fruit stalk goes hand in hand with the development of the fruit.

Methods

In both greenhouse and field culture a much larger number of plants were grown than were used in each experiment. At the beginning of each experiment the strongest plants and those most nearly equal in size were selected, and the others were removed. This was done to reduce the chances, as far as possible, of individual variation.

In the greenhouse cultures, the pots with the plants were placed in a row. The plants were then measured and every other one was taken as a control. At the close of the experiment, an average was taken of all the data on the control, and also the experimental plants in each series. This was the method used by SCHOLTZ. By preliminary experiments, the writer was convinced that it was by far the most satisfactory, on account of individual variations in plants which make it very difficult to select any one plant that will be a fair control throughout the experiment for any one experimental plant.

The methods of BALL and HIBBARD for applying tension by pull in the direction of the longitudinal axis of the stem were followed. The writer was soon convinced, however, that for plants as large as those used in his experiments, the leather noose used by BALL as a tension fastening was not needed. Heavy cotton flannel and ordinary cotton cord, therefore, were used for this purpose in all these experiments. A strip of heavy cotton flannel 2.5^{cm} wide was wrapped at least twice around the stem. Over this, two cords were passed from opposite sides and back again. Each cord, thus passing twice around the stem, was drawn tight enough to keep the fastening from slipping. The ends of each cord were then tied to a second. These were united into one strand some distance above the fastening. This double cord was passed over a light running pulley, supported directly above the plant, and a weight was attached to its free end. A thin

strip of wood or bamboo about 10^{cm} long was placed crosswise between the cords coming up on opposite sides of the stem, to keep them from injuring the young leaves and growing tip of the stem.

In the field cultures, exactly the same methods were followed, except that the seeds were planted in rows. The inferior seedlings were removed, and only the stronger ones were left for experimental use. In most cases the heavy clay loam was sufficiently firm to keep the plants from being pulled up by the tension. In the few cases when the soil was not firm enough, heavy flat weights were used to hold it in place.

METHODS IN FINAL DETERMINATIONS

Method 1.—In all but two experiments the stems were tested by direct pull along their longitudinal axes to determine whether they had responded in a self-regulatory manner to traction by increasing their breaking strength.

Preliminary experiments convinced the writer that the method of obtaining the breaking strength used by BALL was not satisfactory, since too many of the experimental plants broke at or just below the tension fastening. Larger plants therefore were used. These were broken at some distance below the tension fastening, thus eliminating the unquestionably weakening effect coming from the pressure of a tension fastening on the young and tender stem.

For this purpose, a strong wooden frame was constructed, about 120^{cm} long and 50^{cm} high. Through the middle of the frame ran a shelf parallel with top and bottom. On this shelf rested the plant, blocks, and spring balance used in determining the tensile strength. To grasp the ends of the stem, 4 blocks of wood were selected, each being 5^{cm} thick, 10^{cm} wide, and 20^{cm} long. These blocks were laid together in pairs, one block above its mate, and grooves considerably larger than the stems were cut in the contact faces of each pair to receive the plant stem.

During the preliminary experiments, the stems, except in the portion to be tested, were wrapped in moist cotton and then imbedded in a damp mixture of sand and Portland cement. This mixture was placed in the groove of the lower half of the pair of blocks. The stem was then placed in position and more concrete was piled on top.

This was pressed down and around the stem by tightening the bolts which were used to draw the two blocks together. This method was satisfactory. It was soon found, however, that the stem could be held sufficiently firm by substituting moist cotton for the mixture of sand and Portland cement. Moist cotton, therefore, was used in all the experiments as packing to fasten the stem in the blocks.

When the stems were fastened in the blocks, one pair of blocks was hooked to the spring balance, and the other pair was secured to one end of the wooden frame. The spring balance was hooked in turn to an iron rod passing through the opposite upright of the wooden frame. On the end of this rod, protruding beyond the frame, was a large tail-nut. By turning this tail-nut with the hand, tension was brought on the spring balance, and through the balance on the plant stem. The breaking strength was read from the face of the spring balance.

After the stems were broken they were preserved either in 50 per cent. alcohol, or short sections were cut from just below the breaking point in the stems, and these were killed and fixed in 1 per cent. chrom-acetic acid, thoroughly washed, dehydrated in alcohol, and kept for future study.

The following methods were used in making microscopic examinations and measurements of the xylem and hard bast in the stems.

Method 2.—Measurements of the thickness of cell walls in stained free-hand sections, and also in some cases of microtome sections, were made by using an ocular micrometer. The results recorded are in each case an average of eight measurements taken in as many distinct areas of the cross-section.

Method 3.—The total xylem and hard bast areas were measured in some of the experiments by projecting a cross-section of the stem upon a bristol-board screen, and measuring the areas with a polar planimeter.

Method 4.—Camera lucida drawings of the total xylem and hard bast areas and also of the hard bast elements were made upon standardized bristol-board. The drawings were very carefuly cut out with a sharp and pointed scalpel, and then weighed on a chemical balance. The number of hard bast elements were also counted by fastening the drawings of the hard bast elements over sheets of yellow

paper and checking off each element by marking through the lumen on the yellow paper underneath.

Method 5.—The hard bast elements were drawn by means of a camera lucida and then counted to determine whether an increase had resulted in response to the pull.

Method 6.—Radial and tangential microtome sections of acid-fixed material were made to determine whether any fibrous parenchyma existed directly around the hard bast areas. This method was used only on control stems of *Helianthus annuus*. It was the purpose to determine whether the elements which produced the increased number of bast fibers were present before the tension was applied and therefore only developed, or whether they were formed *de novo* in response to tension.

The plants investigated were *Helianthus annuus*, *Phaseolus vulgaris*, *Ricinus communis*, *Sinapis alba*, *Vicia Faba*, *Lupinus albus*, *Rubus occidentalis*, and *Vinca major*.

Experiments

Experiment 1. Helianthus annuus, greenhouse culture.—Ten vigorous plants were selected from a number of seedlings grown in pots 20^{cm} in diameter. The experiment began November 21, 1906, when they were mostly 10 to 15^{cm} in height, and ended 29 days later. The tension fastening was placed on the experimental plants just below the second pair of leaves. The controls were not supported. The pull applied to the experimental plants was gradually increased from 25^{gm} at the start to 300^{gm} on December 14, 1906. The slow growth of these plants may be due to the fact that during the entire experimental period there were only a few sunny days, and also to the shortness of the day at this season of the year.

Table I gives all the data from this experiment, except the following: By method 6, fibrous parenchyma was found in the control stems as a transitional form between the thick-walled hard bast fibers and the short-celled parenchymatous tissue. These longitudinal sections were taken from just above the cotyledons. The increased number of bast fibers in the experimental plants, therefore, may be accounted for as the result of the response of these fibrous cells to tension, which thus develop into hard bast fibers.

The actual area of the cell walls of the hard bast elements and their number was found by method 4, and the total xylem area by method 3.

TABLE I.—*Helianthus annuus*

No. of plant	November 21		November 28		December 14		December 20		Breaking strength in grams	Cell wall area of hard bast elements in grams	No. of hard bast fibers	Xylem area in sq. cm. ×10
	Height in cm.	Diam. in mm.	Height in cm.	Diam. in mm.	Height in cm.	Diam. in mm.	Height in cm.	Diam. in mm.				
Exp.												
1.....	19.	4.	29.	4.	50.4	4.	59.2	4.2	7711	6.837	691	8.8
2.....	13.1	3.2	19.	3.2	34.	4.1	41.6	4.2	5443	7.014	811	6.6
3.....	10.6	3.5	19.	3.5	37.8	3.6	44.7	3.5	5216	6.430	840	4.1
4.....	11.8	3.1	20.7	3.2	35.3	3.6	44.1	3.9	4626	5.488	682	8.8
5.....	9.	2.	20.2	2.	36.5	3.	44.1	3.2	5443	5.666	581	5.2
Total	63.5	15.8	107.9	15.9	194.0	18.3	233.7	19.0	28749	31.435	3605	33.5
Av....	12.7	3.16	21.58	3.18	38.8	3.66	46.74	3.8	5749.8	6.287	721	6.7
Control												
1.....	15.2	3.	22.7	3.	42.8	4.1	52.9	4.3	5352	5.145	597	6.6
2.....	11.3	3.5	17.7	3.5	34.	3.8	42.8	4.	3039	6.420	706	4.3
3.....	11.8	2.5	19.	3.	34.	3.4	41.6	3.5	3719	5.372	657	5.9
4.....	11.3	3.2	18.3	3.2	34.	3.2	39.	3.5	2494	5.498	632	3.7
5.....	9.	2.2	12.1	2.2	23.3	3.2	30.	3.4	3629	4.679	656	3.3
Total	58.6	14.4	89.7	14.9	168.1	17.7	206.3	18.5	18233	27.114	3248	23.8
Av....	11.72	2.88	17.94	2.98	33.62	3.54	41.26	3.7	3647	5.423	641	4.76

The percentages of increase in the experimental plants over the controls are the following: breaking strength 57.6 per cent.; cross-section of walls of hard bast 16 per cent.; number of hard bast elements 12.5 per cent.; and xylem area 40 per cent.

TABLE II.—*Helianthus annuus*

No. of plant	Height in cm.							Height to 2d pair of leaves	Diam. just above 1st pair of leaves in mm.		Distance of break below 2d pair of leaves	Breaking strength in kg
Exp.	June 21	June 22	June 24	June 26	June 28	June 30	July 1	July 1	June 21	July 1	July 1	July 1
Av.....	7.5	8.6	12.6	16.3	19.4	23.8	26.6	10.4	4.1	7.26	3.25	16.535
Control												
Av.....	7.03	8.2	11.3	14.3	17.3	21.5	24.3	9.2	4.1	7.43	3.72	13.799

Experiment 2. Helianthus annuus, field culture.—After the inferior plants had been removed, those used in this experiment stood 15 to 20^{cm} apart in the row. Every other plant was used as a control. The tension fastening was placed just below the second pair of leaves on the experimental plants. The control plants were left free. The experiment began June 21, 1907, and ended ten days later. A tension of 250^{gm} was applied to the experimental plants at the beginning of the experiment. This was increased to 750^{gm} the following day and to 1900^{gm} on June 25.

Table II gives an average of the measurements and the breaking strength of these plants. The average increase in breaking strength for the experimental plants over the controls was 2736^{gm} or 19.6 per cent.

The height measurements in this experiment confirm the work of SCHOLTZ and HEGLER (**'93**), showing a lessening of growth during the first 24 hours, followed by an increased growth for the next four days.

TABLE III.—*Helianthus annuus*

No. of plant	Height in cm.		Height to 4th pair of leaves		Diam. just above 1st pair of leaves in mm.		Diam. just above 2d pair of leaves in mm.		Distance of break above ground in cm.	Breaking strength in kg.
	July 18	July 30	July 18	July 30	July 18	July 30	July 18	July 30	July 30	July 30
Exp. Av.....	36.07	89.6	32.33	44.6	9.4	15.95	7.58	13.39	12.3	69.99
Control Av.....	38.01	90.5	34.6	45.08	9.64	16.03	7.69	14.37	13.9	66.12

Experiment 3. Helianthus annuus, field culture.—Much older and larger plants than those used in experiment 2 were put under tension July 18, 1908. This was gradually increased from 200^{gm} at the start to 1950^{gm} on July 27. The experiment ended July 30. It was the purpose in this experiment to determine whether the same tension would have the same influence on larger and older stems as on younger and less woody ones. The average increase in breaking strength as shown in table III in response to a tension of practically 1900^{gm} was 3.87^{kg}, while in experiment 2 the increase for a period of 10 days was 2.74^{kg}. The increase as a percentage of the average

breaking strength of the controls in this experiment, 5.8 per cent., was much less than in experiment 2, since the breaking strength was so much greater.

The tension fastenings were made just below the fourth pair of leaves. Similar fastenings were made on the control plants, and from these the plants were fastened to upright supports to keep them from being swayed by the wind.

Experiment 4. Sinapis alba, field culture.—These plants grew approximately 15^{cm} apart in the row. Every other plant was used as a control. The tension fastening was placed just below the seventh node above ground. Similar fastenings were placed on the control plants. From these fastenings, the plants were attached to strong cords, stretched one on each side of the row and parallel to it. A weight of 250^{gm} was attached to the experimental plants on July 16, 1907, and gradually increased to 1150^{gm} on July 24. The experiment ended two days later. The details of this experiment are given in table IV. The average increase of the breaking strength of the experimental over the control plants was 4.8^{kg} or 32 per cent.

The anatomical structure of these stems was determined by methods 2, 3, 4, and 5. Free-hand sections were made of all the stems about 5^{mm} below the point where they broke. These sections were stained in anilin safranin and mounted in glycerin. All the slides were then taken by a second party who labeled them with a secret label. The measurements given in table IV were then made, after which the second party gave me the key to the labels. The measurements of the experimental plants were now separated from those of the controls. An average of each set shows a decrease of 10 per cent. in the total xylem area and an increase in the thickness of the xylem cell walls of 5 per cent. The increase in hard bast in 5 stems which were selected wholly by chance was 52 per cent. The increase of hard bast elements in the same stems was 38 per cent.

The total xylem area for the five stems in which the hard bast determinations were made was also measured by method 4, with results that agreed within less than one-half of 1 per cent. with the measurements made by method 3.

The hard bast in the controls was lignified in all but a few stems, where it was only partly lignified. Stem 18 showed the least lignifi-

TABLE IV.—*Sinapis alba*

No. of plant	Height in cm.		Height to fastening in cm.		Diam. just above ground in mm.		Distance of break above ground in cm.	Breaking strength in kg.	Cell wall area of hard bast elements in grams	No. of hard bast elements	Xylem area in sq. cm. X10	Average thickness of xylem cell walls in microns
Exp.	July 16	July 26	July 16	July 26	July 16	July 26	July 26	July 26	July 26	July 26	July 26	July 26
1	18.3	60.	15.	23.	6.85	9.25	16	28.09	.....	.....	15.88	2.812
2	25.	55.5	19.	21.5	5.1	7.3	13	16.76	.....	.....	6.99	2.625
3	22.	56.0	17.2	19.	5.	6.07	8	21.29	.....	.....	7.62	4.312
4	14.8	48.5	12.	16.	4.65	7.5	7	24.46	.....	.....	12.70	3.437
5	19.	53.5	14.	18.	5.1	7.15	12	11.79	.....	.....	9.84	2.500
6	23.5	60.	18.5	23.	5.95	8.8	13	21.74	.....	.....	8.67	2.562
7	20.5	57.	15.5	21.	7.2	9.35	13	12.23	.....	.....	8.89	2.812
8	24.	70.	20.	22.	7.4	9.9	16	16.76	11.395	656	10.70	2.562
9	26.4	72.	21.8	30.5	7.45	9.33	20	24.92	11.801	861	11.11	3.124
10	24.	68.	21.	31.	6.05	7.32	21	28.09	7.061	561	9.53	3.625
11	27.	69.	22.7	29.	5.85	8.3	16	22.20	.....	.....	10.70	3.375
12	27.5	67.	20.5	26.	6.55	8.65	14	32.62	.....	.....	8.89	4.625
13	27.	72.	21.	29.	5.75	7.65	12	16.76	.....	.....	9.84	3.687
14	24.7	62.	20.8	26.	6.45	8.1	15	17.21	.....	.....	12.70	3.375
15	27.5	62.	19.8	21.	5.4	5.77	12	17.21	5.938	578	3.18	3.037
16	26.3	68.	23.	26.	47.	6.75	7	25.82	4.598	526	7.94	2.875
17	25.8	59.	21.5	26.	4.6	5.2	15	11.33	.....	.....	5.40	2.625
18	28.3	67.	22.	25.	5.15	6.5	8	18.57	.....	.....	8.26	3.000
19	17.	46.	14.	19.	4.1	7.1	7	7.70	.....	.....	9.53	2.750
Total	503.0	1172.5	359.3	452.0	109.3	145.99	245.	375.55	40.791	3182	178.37	59.720
Average	23.6	61.7	18.9	23.8	5.75	7.68	12.9	19.77	8.158	636	9.39	3.143

TABLE IV.—*Sinapis alba* (*continued*)

No. of plant	Height in cm.		Height to fastening in cm.		Diam. just above ground in mm.		Distance of break from ground in cm.	Breaking strength in kg.	Cell wall area of hard bast elements in grams	No. of hard bast elements	Xylem area in sq. cm. × 10	Average thickness of xylem cell walls in microns
Control	July 16	July 26	July 16	July 26	July 16	July 26	July 26	July 26	July 26	July 26	July 26	July 26
1	23.4	55.5	20.	24.	5.10	7.25	15.	15.40	.....	.....	7.30	3.187
2	26.3	63.	20.5	24.5	6.10	8.90	7.	15.41	.....	.....	11.43	3.062
3	17.2	50.	14.6	17.5	4.15	5.75	13.	9.97	.....	.....	3.81	2.562
4	20.3	63.	15.4	19.5	5.60	7.70	12.	19.94	.....	.....	9.53	2.937
5	18.8	58.	14.5	19.5	5.35	8.22	15.	19.94	7.075	542	12.70	3.062
6	26.	60.	22.5	34.	8.00	10.62	19.	10.41	.....	.....	19.05	3.000
7	22.7	64.	17.5	21.5	7.20	9.35	10.	11.79	4.714	365	16.51	2.562
8	24.4	63.	19.5	22.	6.20	8.73	7.	11.33	.....	.....	7.62	3.000
9	21.7	66.	16.3	22.	7.00	8.63	5.	15.86	.....	.....	10.80	3.062
10	26.3	66.	22.3	33.5	7.15	10.30	19.	21.74	.....	.....	19.69	2.437
11	21.9	58.	18.0	20.	5.15	6.10	8.	9.51	.....	.....	6.35	3.437
12	28.5	70.	28.3	34.5	6.30	7.00	17.	19.03	5.709	510	8.25	2.875
13	28.7	62	21.4	24.	5.60	6.25	7.	13.13	.....	.....	6.35	4.062
14	25.8	66.	21.5	28.	5.80	7.72	13.	16.76	.....	.....	11.43	3.375
15	27.7	79.	21.5	24.	5.00	6.55	8.	12.68	5.040	491	6.67	3.125
16	24.5	57.	20.5	24.	6.10	7.80	7.	17.21	.....	.....	11.43	2.500
17	31.5	73.	25.0	27.	5.20	6.00	12.	25.86	.....	.....	6.03	3.062
18	26.3	51.	21.8	23.	4.40	7.50	13.	5.54	4.159	395	8.89	2.500
19	26.5	61.	22.5	24.	5.40	7.45	8.	14.50	.....	.....	13.07	3.500
20	19.5	53.	16.3	20.	4.80	9.10	10.	13.59	.....	.....	13.27	2.561
Total	488.0	1237.5	396.9	486.5	115.60	156.92	225.	298.60	26.697	2305	205.19	59.868
Average	24.4	61.87	19.84	24.32	5.78	7.85	11.25	14.93	5.339	461	10.51	2.993

cation among the controls. Stems 5, 7, 12, and 15 were all well lignified. The hard bast in approximately 10 per cent. of the experimental stems was completely lignified. In the five stems for which the hard bast determinations were made, only a few elements were lignified in 8 and 9, while in 16 lignification of the hard bast was almost complete.

Experiment 5. Phaseolus vulgaris, greenhouse culture.—The plants for this experiment were grown and selected in a like manner to those for experiment 1. The tension fastening was placed just below the second pair of leaves. The experiment began October 21 and ended November 8, 1907. The weight attached to the experimental plants, 400^{gm} at the beginning, was increased to 950^{gm} after five days, and to 1150^{gm} November 5. The controls were left unsupported.

TABLE V.—*Phaseolus vulgaris*

No. of plant	Height in cm.		Height to 2d pair of leaves in cm.		Diam. just above ground in mm.		Diam. just above cotyledons in mm.		Place where stem broke	Breaking strength in kg.	Bast area in sq. cm. ×125	Xylem area in sq. cm. ×20
Exp.	Oct. 21	Nov. 8	Oct. 21	Nov. 8	Oct. 21	Nov. 8	Oct. 21	Nov. 8	Nov. 8	Nov. 8	Nov. 8	Nov. 8
Av.....	13.5	25.	12.1	14.1	4.34	4.82	3.1	3.3	.....	6.795	88.08	6.59
Control												
Av.....	13.3	20.8	12.0	12.8	4.16	4.53	2.98	3.34	.....	5.098	76.57	5.42

The average measurements and results of this experiment are given in table V. The breaking strength shows an increase in the experimental plants over the controls of 1.7^{kg}, or 33 per cent. Sections taken just below the breaks showed an increase of 15 per cent. in the area of hard bast, and 22 per cent. in the area of the xylem. These measurements were made by method 3. The hard bast and xylem were equally lignified in experimental and control plants.

Experiment 6. Phaseolus vulgaris, greenhouse culture.—These plants, when the experiment was started, were ten days older than those used in experiment 5. The experiment began December 7, 1907, and ended January 7, 1908, at which date most of the blossoms had already fallen from the plants and the leaves were beginning to lose their chlorophyll. A weight of 250^{gm} attached to the experi-

mental plants at the beginning of the experiment was gradually increased to 900^{gm} on December 20. It was the purpose of this experiment to determine, by prolonging the experimental period and growing the plants to maturity, whether the response in the earlier and actively growing period was continued to the end of the vegetative period. For this reason no additional weights were added after December 20. Both experimental and control plants broke with almost the same weight. The experimental plants were much more brittle and in most cases broke with a smooth, clear break, while the controls showed more of the elasticity and toughness which was characteristic of the stems in experiment 5.

Experiment 7. Phaseolus vulgaris, greenhouse culture.—After finding that response to tension, if any had occurred in experiment 6, was vitiated by permitting the plants to grow to maturity, experiment 5 was repeated, beginning March 5 and ending fourteen days later. The weights used, 200^{gm} at the beginning, were increased to 450^{gm} March 9 and to 700^{gm} four days later. The experimental plants showed an average increase in breaking strength of 3.32^{kg}, or 42.5 per cent. The number of hard bast elements was determined by method 5. The experimental plants showed an average increase of 167, or 14.9 per cent. The results of this experiment, therefore, agree with those of experiment 5. The tension fastening in this and also in experiment 6 was made at the same place as in experiment 5.

Experiment 8. Vinca major, greenhouse culture.—In selecting plants for this experiment those were taken which had young and actively growing shoots, uniform in general appearance and length. No measurements were taken at the beginning of the experiment, December 1, 1906. The experimental shoots were put under a tension of 50^{gm} at the beginning, which was gradually increased to 300^{gm} on December 21. The control plants were fastened to an upright support, but were not under tension.

The breaking strength was tested in the internode just below the fastening which was in an active growing condition in each plant when the experiment was started. The average shows an increase in the experimental plants of 649^{gm}, or 15.2 per cent.

Experiment 9. Vinca major, greenhouse culture.—It was the purpose of this experiment to determine whether internodes which

were no longer elongating would respond to tension by increasing their breaking strength. For this reason, shoots older and larger than those in experiment 8 were used. The controls were supported as in experiment 8. A weight of 200^{gm} attached to the experimental shoots on November 15, 1907, was increased to 400^{gm} on December 14. The experiment ended January 8, 1908.

The third instead of the last internode below the tension fastening was tested for its breaking strength. No elongation and in many cases no growth in diameter took place in this internode. An average of the breaking strengths shows no response to tension for an internode which is no longer actively growing.

TABLE VI.—*Vinca major*

RECORD A

No. of plant	Height in cm.		Height to node just above fastening in cm.		Diam. just below fastening in cm.		No. of node just above fastening	Distance of breaking point below fastening in cm.	Breaking strength in kg.	Thickness of xylem cell walls in microns	Weight of xylem area in grams	Thickness of hard bast fibers in microns	No. of hard bast fibers
	Jan. 9	Jan. 25	Jan. 9	Jan. 25	Jan. 9	Jan. 25			Jan. 25				
Exp. Av....	29.	41.4	25.6	27.3	2.11	2.22	.....	8.25	4.53	.....	.....	.....	.....
Control Av....	32.	44.	28.4	29.6	2.09	2.20	.....	8.75	4.24	.....	.....	.....	.....

RECORD B

		Mar. 2		Mar. 2		Mar. 2			Mar. 2	Mar. 2	Mar. 2	Mar. 2	Mar. 2
Exp. Av. . .	29.2	95.2	27.	29.1	2.05	2.38	.....	15	8.22	5.77	.2777	7.42	1276
Control Av. . .	28.6	62	26.	28.5	2.1	2.32	.....	12.1	6.97	5.09	.2140	6.56	1297

Experiment 10. Vinca major, greenhouse culture.—This experiment was in large measure a repetition of experiment 8. Tension fastenings were made on all the shoots. Just enough weight was attached to the control shoots to hold them erect. The experiment began January 9, 1908, with a weight of 250^{gm} attached to the experimental plants. This was increased to 450^{gm} eight days later, and to 900^{gm} January 25. The internode to which the tension fastening was attached was in each case actively elongating at the beginning of the

experiment. One-half of the shoots were removed and tested January 25, i. e., after 16 days and subjection to a maximum tension of 450^{gm}. Table VI, record A, gives an average of the results for this part of the experiment. The average breaking strength is slightly increased in the experimental shoots.

The remaining shoots were tested March 2, 1908. An average of breaking strengths as given in table VI, record B, shows an increase in favor of the experimental shoots of 1.25^{kg} or 18 per cent. A study of the anatomical structure of these stems was made by methods 2, 4, and 5. These determinations show an increase of 30 per cent. in the entire xylem area, an increase in xylem wall thickness of 13 per cent., and the same increase in the thickness of the walls of the hard bast fibers. A count of the hard bast fibers showed no increase in the number of these elements.

Experiment 11. Ricinus communis, field culture.—The method in this experiment was the same as in experiment 2. The tension fastening was placed just below the second pair of leaves. The control plants were not supported. The experiment began July 20 and ended August 1. A tension of 300^{gm} at the beginning was gradually raised to 2350^{gm} two days before the experiment ended.

TABLE VII.—*Ricinus communis*

No. of plant	Height in cm.		Height to 2d pair of leaves in cm.		Diam. at base in mm.		Diam. just above 1st pair of leaves in mm.		Breaking strength in kg.	Distance of break from ground in cm.	Xylem area in sq. cm. ×10	Av. xylem cell wall thickness in microns
	July 20	Aug. 1	July 20	Aug. 1	July 20	Aug. 1	July 20	Aug. 1	Aug. 1	Aug. 1	Aug. 1	Aug. 1
Exp. Av.....	24.4	44.83	16.25	17.77	8.18	12.18	10.66	13.01	43.86	10.24	27.07	3.038
Control Av.....	22.8	43.8	16.4	19.6	8.44	11.41	9.95	12.56	41.22	10.4	25.99	2.929

The average results, given in table VII, show 43.86^{kg} as the average breaking strength for the experimental plants and 41.22^{kg} for the controls, or 6.4 per cent. The increase is slightly greater than the final weight which was attached to the experimental plants. The average xylem wall thickness and total xylem area, as determined by methods 2 and 3, show an increase respectively of 0.1μ and 4 per cent.

The bast fibers were not well defined; many of them only very slightly thickened. It was therefore impossible to make an accurate count of their number.

Experiment 12. Rubus occidentalis, field culture.—On June 25, 1907, ten young stems were selected which in general appearance were equally vigorous. Tension fastenings were placed on five of these approximately 35^{cm} from the ground. The controls were left free. A weight of 2.25^{kg} at the beginning was increased to 4.5^{kg} on July 6, and to 9^{kg} 24 days later. The experiment ended September 30.

The decrease in height in the experimental plants was very marked. Growth in diameter was also less. The total bast and xylem areas were determined by method 3, giving an average increase in bast of 13.6 per cent. over the controls, but a decrease in xylem of 30 per cent. This decrease may be partly attributed to the reduced growth in diameter of the experimental plants.

Experiment 13. Vicia Faba, greenhouse culture.—The experimental plants were put under tension on October 24, 1907, the fastening being placed just below the fifth node. Since *Vicia Faba* grows very rapidly, it was thought possible that it might respond to a stronger tension than that applied to stems of other species of like cross-section and age. A weight of 450^{gm}, therefore, was applied at the beginning, increased to 900^{gm} two days later, and to 1300^{gm} on November 6. Since illumination is greatly reduced at this time of the year and growth is comparatively slow, this large weight caused the stem to elongate more rapidly than the control. This was accompanied by diminished growth in diameter. The control plants were left free, and since *Vicia Faba* retains its orthotropic position with great difficulty, these grew larger in diameter and less in height. When the experiment ended on November 9, the breaking strength of the experimental plants was less than the breaking strength of the controls.

Experiment 14. Vicia Faba, greenhouse culture.—The results of experiment 13 gave cause for this experiment, in which an effort was made to eliminate or at least minimize the effect of those factors which may have obscured the response to tension in the last experiment, if such a response did occur. For this reason, the experiment was carried on during the season of the year when illumination was much stronger and hence the chances for growth much better, all other

factors affecting growth remaining unchanged. Smaller weights also were used on the experimental plants, and the control plants were supported by small weights, barely sufficient to counterbalance the weight of plant, attached as the larger weights were to the experimental plants, the cords running over pulleys. The experimental and control plants were now growing under exactly the same conditions, except that the former were subject to tension of 200^{gm} at the beginning, increased to 450^{gm} on March 19, and to 700^{gm} on March 23, and finally to 950^{gm} on March 30. The experiment ended April 6.

TABLE VIII.—*Vicia Faba*

No. of plant	Height in cm.		Height to 4th node in cm.		Diam. just above 1st leaf in mm.		Diam. just below 4th node in mm.		Distance of breaking point above ground in cm.	Breaking strength in kg.	No. of hard bast fibers	Xylem area in sq. cm. × 18
	Mar. 14	Apr. 6	Mar. 14	Apr. 6	Mar. 14	Apr. 6	Mar. 14	Apr. 6	Apr. 6	Apr. 6	Apr. 6	Apr. 6
Exp. Av.....	21.3	69.8	15.9	20.3	5.6	8.49	4.82	6.33	8.8	24.91	1630.3	22.75
Control Av.....	22.4	66.	15.3	18.0	6.01	8.40	4.80	6.39	9.3	20.59	1419.4	21.00

The results are given in table VIII. The breaking strength shows an increase of 4.35^{kg} or 21 per cent. for the experimental plants over the controls. The number of hard bast fibers, determined by method 5, and the total xylem area by method 3, show an increase in the former of 14.8 per cent., and in the latter of 8.3 per cent.

TABLE IX.—*Lupinus albus*

No. of plant	Height in cm.		Height to cotyledons in cm.		Diam. half-way between ground and cotyledons in mm.		No. of hard bast fibers	Xylem area in grams
	Mar. 2	Mar. 30	Mar. 2	Mar. 30	Mar. 2	Mar. 30	Mar. 30	Mar. 30
Exp. Av.....	4.74	9.02	3.54	5.06	3.71	2.91	839.4	.9127
Control Av.....	4.7	6.95	3.55	3.97	3.70	2.97	755	.800

Experiment 15. Lupinus albus, greenhouse culture.—This experiment began March 2 and ended March 30, the experimental plants

being subjected to a tension of 250^{gm} at the beginning, increased to 500^{gm} seven days later, and to 750^{gm} on March 19. On account of the shortness of the stems, which made it impossible to fasten them into the apparatus firmly enough to hold a sufficient weight, the attempt to determine the breaking strength of these stems was unsatisfactory. The reduced diameter, in that part of the stem below the cotyledons as shown in table IX, was due to a collapse of the tissue surrounding the stele. The total xylem area and number of hard bast elements, determined by methods 4 and 5, show an average increase of the former to be 14 per cent. and of the latter 11 per cent.

Summary

An average of the different determinations made in the foregoing experiments is given in table X. In all except experiment 9 with *Vinca major* and experiment 13 with *Vicia Faba*, the average breaking strength in the 246 tests shows an increase in the experimental plants over the controls. This must be attributed to a response to traction along the longitudinal axis of the stem. The negative results in experiment 9 show that the older part of the stem, where active growth has ceased, does not respond by increasing its breaking strength. The lack of response in experiment 13 with *Vicia Faba* can be attributed to factors which vitiated the influence of tension. These conditions are fully explained in experiments 13 and 14. Experiments 9 and 13, therefore, may be left out of consideration. The average area of the cell wall of the hard bast elements shows an increase in the experimental plants over the controls for *Helianthus annuus* and *Sinapis alba*. This determination was not made for the other species investigated. The average number of hard bast elements shows an increase in the experimental plants over the controls in all the species for which this determination was made, except *Vinca major*. *Phaseolus vulgaris* and *Rubus occidentalis* also show an increase of total bast area in the experimental plants over the controls. The average thickness of the hard bast fibers in *Vinca major* was found to be greater for the experimental stems.

In the total xylem area determinations, the only decrease was in *Sinapis alba* and *Rubus occidentalis*, in both of which, however, there

was an increase in hard bast. The other species all responded to tension by increasing their xylem area. The average thickness of

TABLE X.—SUMMARY

No. of experiment	Name of plant	Average breaking strength in kg.	Average cell wall area of hard bast fibers	Average no. of hard bast fibers	Average total hard bast area	Average thickness of hard bast cell walls	Average total xylem area	Average thickness of xylem cell walls	No. of stems used
Exp. 1...	Helianthus annuus	5.750	6.287	721	.....	.....	6.70	....	5
Cont. 1..	Helianthus annuus	3.647	5.423	641	.....	.....	4.76	.....	5
Exp. 2...	Helianthus annuus	16.535	.....	.....	.....	.....	.....	.....	12
Cont. 2..	Helianthus annuus	13.799	.....	.....	.....	.....	.....	.....	13
Exp. 3...	Helianthus annuus	69.990	.....	.....	.....	.....	.....	.....	12
Cont. 3..	Helianthus annuus	66.120	.....	.....	.....	.....	.....	.....	11
Exp. 4...	Sinapis alba	19.770	8.158	636	.....	.....	9.39	3.143	19
Cont. 4..	Sinapis alba	14.930	5.339	461	.....	.....	10.51	2.093	20
Exp. 5...	Phaseolus vulgaris	6.795	.....	.....	88.08	.....	6.59	.....	4
Cont. 5..	Phaseolus vulgaris	5.098	.....	.....	76.57	.....	5.42	.....	4
Exp. 6...	Phaseolus vulgaris	5.850	.....	.....	.....	.....	.....	.....	11
Cont. 6..	Phaseolus vulgaris	5.570	.....	.....	.....	.....	.....	.....	13
Exp. 7...	Phaseolus vulgaris	10.135	.....	1288	.....	.....	.....	.....	4
Cont. 7..	Phaseolus vulgaris	7.815	.....	1121	.....	.....	.....	.....	4
Exp. 8...	Vinca major	5.903	.....	.....	.....	.....	.....	.....	5
Cont. 8..	Vinca major	4.254	.....	.....	.....	.....	.....	.....	4
Exp. 9...	Vinca major*	6.560	.....	.....	.....	.....	.....	.....	15
Cont. 9..	Vinca major*	6.790	.....	.....	.....	.....	.....	.....	15
Exp. 10B	Vinca major	8.220	.....	1276	.....	7.42	.2777	5.77	4
Cont. 10B	Vinca major	6.070	.....	1297	.....	6.56	.2141	5.09	4
Exp. 11..	Ricinus communis	43.860	.....	.....	.....	.....	27.07	.....	12
Cont. 11.	Ricinus communis	41.220	.....	.....	.....	.....	25.99	.....	12
Exp. 12..	Rubus occidentalis	.....	.....	.....	0.167	.....	1.216	.....	5
Cont. 12.	Rubus occidentalis	.....	.....	.....	0.147	.....	1.762	.....	5
Exp. 13..	Vicia Faba*	7.190	.....	.....	.....	.....	.....	.....	8
Cont. 13	Vicia Faba*	8.090	.....	.....	.....	.....	.....	.....	7
Exp. 14..	Vicia Faba	24.910	.....	1630	.....	.....	22.75	....	7
Cont. 14.	Vicia Faba	20.590	.....	1419	.....	.....	21.00	.....	8
Exp. 15..	Lupinus albus	.....	.....	839	.....	.....	.9127	.....	5
Cont. 15.	Lupinus albus	.....	.....	755	.....	.....	.8000	.....	6

* See experiments for explanations of negative results.

xylem cells walls in *Sinapis alba* and *Vinca major* was also greater in the experimental stems than the controls.

Conclusion

The results of the foregoing experiments have convinced the writer conclusively that actively growing stems of the herbaceous plants investigated and of *Vinca major* respond to traction along their longitudinal axes, by increasing their breaking strength; also by an increased development of bast or of xylem, and in most cases by an

increase of both these mechanical tissues. The experimental evidence for *Rubus occidentalis* was too limited to be conclusive. The stems were already too old and mature when the experiment was started. The writer is convinced, however, by this experiment with *Rubus occidentalis*, that the tension used by WIEDERSHEIM (**29**) on pendant woody branches was not sufficient to send a stimulus past the stimulus threshold.

UNIVERSITY OF MICHIGAN

LITERATURE CITED

1. BALL, O. M., Der Einfluss von Zug auf die Ausbildung von Festungsgewebe. Jahrb. Wiss. Bot. **39**:305. 1904.
2. BARANETZKY, Die tägliche Periodizität im Langenwachsthum der Stengel. Mém. Acad. St. Petersb. **27**:2. 1879.
3. BOODLE, L. A., On lignification of phloem in *Helianthus annuus*. Annals of Botany **16**:180. 1902.
4. DARWIN, C., On the movements and habits of climbing plants. Jour. Linn. Soc. London **9**. Also reported in GRAY, A., *q. v.*
5. DENNERT, E., Anatomische Metamorphose der Bluthenstandaxen. Bot. Heft. Forsch. Bot. Gart. Marburg **2**:128–217. 1887. Abstract in Bot. Jahresb. **15**^{2}:647. 1887.
6. FITTING, H., Weitere Untersuchungen zur Physiologie der Ranken. Jahrb. Wiss. Bot. **39**:424. 1904.
7. GOEBEL, K., Organography of plants (Eng. ed.) **1**:206. 1900.
8. GRAY, ASA, Scientific papers of Asa Gray **1**:176. 1889.
9. HEGLER, R., reported by PFEFFER, *q. v.*
10. ———, Ueber den Einfluss des mechanischen Zugs auf das Wachsthum der Pflanze. Beitr. Biol. Pfl. **6**:383. 1893.
11. HIBBARD, R. P., The influence of tension on the formation of mechanical tissue in plants. BOT. GAZETTE **43**:361. 1907.
12. KELLER, H., Ueber den Einfluss von Belastung und Lage auf die Ausbildung des Gewebes in Fruchtstielen. Inaugural Dissertation, Kiel. 1904.
13. KLEIN, O., Beiträge zur Anatomie der Inflorescenzen. Inaugural Dissertation, Berlin. 1886.
14. KNIGHT, T. A., Phil. Trans. Roy. Soc. London **2**:277. 1803.
15. KÜSTER, E., Beiträge zur Kenntniss der Gallenanatomie. Flora **87**:173. 1900.
16. LABORIE, E., Sur l'anatomie des pedoncles, comparée á celle. . . . . Compt. Rend. Acad. Sci. Paris **99**:1086. 1884. Abstr. in Bot. Jahresb. **12**^{1}:273. 1884.
17. MACDOUGAL, D. T., The mechanism of curvature of tendrils. Annals of Botany **10**:373. 1896.

18. MÜLLER, OTTO, Untersuchungen über die Ranken der Cucurbitaceen. Beitr. Biol. Pfl. **4**:97. 1887.
19. NEWCOMBE, F. C., The regulatory formation of mechanical tissue. BOT. GAZETTE **20**:441. 1895.
20. PEIRCE, G. J., Plant physiology 241. 1903.
21. PFEFFER, W., Untersuchungen R. HEGLER's über den Einfluss von Zugkraften auf die Festigkeit und die Ausbildung mechan. Gewebe im Pflanzen. Ber. Kgl. Sachs. Gesells. Wiss. Math.-Phys. Cl. **43**:638. 1891.
22. ———, Pflanzenphysiologie **2**:148. 1901.
23. PIETERS, A. J., The influence of fruit-bearing on the development of mechanical tissue in some fruit trees. Annals of Botany **10**:511. 1896.
24. REICHE, K., Beiträge zur Anatomie des Inflorescenzen. Ber. Deutsch. Bot. Gesells. **5**:310. 1887.
25. RICHTER, J., Ueber Reactionen der Characeen auf äussere Einflusse. Flora **78**:419. 1894.
26. SCHOLTZ, M., Ueber den Einfluss von Dehnung auf das Langenwachsthum der Pflanzen. Beitr. Biol. Pfl. **4**:323. 1887.
27. VÖCHTING, H., Zur experimentellen Anatomie. Nachr. Kgl. Gesells. Wiss. Gottingen, Math.-Phys. Cl. **38**:278. 1902.
28. VON DERSCHAU, M., Der Einfluss von Kontakt und Zug auf rankende Blattstiele. Inaugural Dissertation, Leipzig. 1893.
29. WIEDERSHEIM, W., Ueber den Einfluss der Belastung auf die Ausbildung von Holz und Bastkörper bei Trauerbäumen. Jahrb. Wiss. Bot. **38**:41. 1903.
30. WORGITZKY, Vergleichende Anatomie der Ranken. Flora **69**:79. 1887.

THE MODIFIABILITY OF TRANSPIRATION IN YOUNG SEEDLINGS

JOSEPH Y. BERGEN

(WITH FIVE FIGURES)

The writer has often noticed the fact that young seedlings (e. g., of Cucurbita and Phaseolus) grown under bell glasses wilted almost at once when exposed to the dry air of a furnace-heated or steam-heated room. Gardeners all know that plants started in cold frames must be "hardened" by gradual exposure to the ordinary atmosphere, brought about by lifting slightly the sashes with which the cold frames are covered.

It appeared worth while to investigate quantitatively the rate of transpiration of these tender seedlings, grown in an extremely moist atmosphere, and the simplest possible case for study seemed to be that of annuals, for these cannot be supposed to have inherited a tendency to develop extreme adaptations to an abnormally moist atmosphere during part of the brief lifetime of the individual plant. Seedlings of the following species were grown in well-watered earth, some under glass cases with air-tight joints, and others in the free air of a furnace-heated room.

Cucumis sativus
Ipomoea purpurea
Lupinus albus
Mirabilis Jalapa
Nicotiana "Sanderae"
Oxalis corniculata
Phaseolus vulgaris
Salvia splendens
Sinapis alba

The temperature was on the average about the same for the covered and the uncovered plants; the former, of course, received a trifle less light than the latter. The moisture of the atmosphere about the leaves naturally differed greatly. Those in glass cases were in a nearly or often quite saturated atmosphere. Those in the free air of the room were in an atmosphere of which the relative humidity during the winter months ranged from 16 to 32 per cent., averaging less than 25 per cent. This is drier than the average summer atmosphere of an oasis in the Sahara. Some plants were also grown in a

greenhouse, where the relative humidity was usually not far from 60 per cent.[1]

In general the plants grown in nearly saturated air and in dry air or in that of moderate humidity presented considerable contrasts in their development.[2] Those from moist air were taller, more slender, longer-leaved, less hairy (if the plant were naturally pubescent), with

FIG. 1.—Ipomoea plants, moist-air form and dry-air form. ×¾. Photographed by ROBERT CAMERON.

thinner, lighter-colored, more pliable, and more translucent leaves. In many cases the moist-air plants showed an accelerated development, producing more leaves in a given time and flowering earlier than those in drier air. Most of the exact measurements of relative

[1] The writer's thanks are due to Professor GEORGE L. GOODALE of Harvard University for the use of space in the greenhouses of the university.

[2] See WIESNER, J., Formänderungen von Pflanzen bei Cultur im absolut feuchten Raume und im Dunkeln. Ber. Deutsch. Bot. Gesells. 9:46–531. 1891.

development were made on plants of Phaseolus. In different lots of these, the moist-air individuals were 15 to 40 per cent. taller than those grown in drier air. The leaves of the former were sometimes as much as 80 per cent. longer than those of the latter, the difference being largely in the petioles. On the other hand, the diameter of the first internode above the cotyledons was (in plants grown in the greenhouse) 30 per cent. greater for those outside the moist glass cases. For house-grown plants the leaf thickness was 25 to 40 per cent. greater in the dry-air plants, and for those grown in the greenhouse

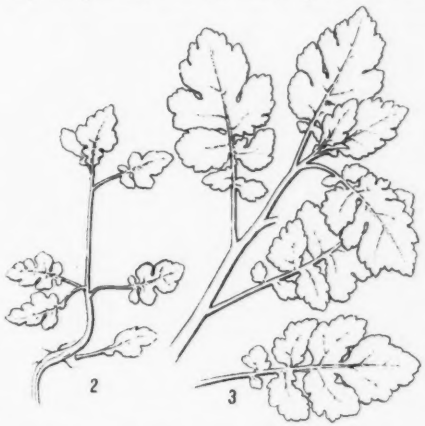


FIG. 2. Sinapis, entire stem and leaves, moist-air form. ×⅓.—FIG. 3. Sinapis, upper half of stem and leaves, dry-air form. ×⅓.

it was 25 per cent. greater than for those under glass cases. The most notable differences in growth of dry-air and moist-air individuals were shown by Ipomoea, in which the moist-air specimens were twining freely, when dry-air specimens of the same age had relatively short internodes and showed no tendency to twine (*fig. 1*). Mirabilis plants in nearly saturated air, by the time the second pair of true leaves had spread apart, were three times as tall as those grown in house air and much more slender. Sinapis, on the other hand, appears depauperate when grown in nearly saturated air, as shown in *figs. 2, 3*. The leaves of Sinapis, and of Cucumis also, in very moist air often show the less indented margin referred to by WIESNER.[3]

3 WIESNER, J., Biologie der Pflanzen 65, 66. Wien. 1902.

The relative translucency of moist-air leaves and dry-air leaves was approximately measured in the case of Nicotiana and of Ipomoea by blue-printing them with various terms of exposure to sunlight, until an equal degree of blueness was obtained for the portions of paper covered by each kind of leaves.[4] The moist-air leaves of Ipomoea were found to be 3.5 times as translucent as the others, and those of Nicotiana 3 times. In the latter plant many of the first leaves grown in moist air stand nearly vertical, while those of the dry-air plants form approximate rosettes. This vertical growth of the moist-air leaves is exactly the reverse of the epinasty of the leaves of *Sempervivum tectorum* and *Oxalis floribunda* noted by WIESNER.[2] The differences in form and size between Nicotiana leaves and Ipomoea leaves grown under moist and under dry conditions are shown in *figs. 4, 5*.

The histology of the leaves studied did not differ nearly as much as it often does in sun plants and shade plants of the same species. In house-grown individuals of Phaseolus, leaves developed in dry air exceeded in thickness those in the glass cases by 25 to 33 per cent., the upper epidermis of the former was about 25 per cent. thicker, and the palisade layer was a little thicker. On the other hand, moist-air leaves of Sinapis were found to be a little thicker, and of Ipomoea sometimes 25 per cent. thicker, than leaves of these genera grown in dry air. As might have been expected, less notable differences were found between leaves grown in air nearly saturated with moisture and those grown in the moderately moist air of the greenhouse.

The behavior of moist-air leaves and dry-air leaves, on being deprived of a water supply and exposed to air at a temperature of about 21° C. and 25 per cent. relative humidity, differs greatly. If a shoot of each kind is cut and exposed to such air, in many cases (Brassica, Cucumis, Ipomoea, Oxalis, Phaseolus) wilting begins in from 0.5 to 2 minutes. Even if the shoots are cut under water and kept with the cut end always submerged, wilting is prompt and continuous. Shoots of Phaseolus were cut and laid in sunshine, in air of humidity probably below 25 per cent., at a temperature of 23°.3 C. One shoot was from the saturated air of the glass case, the other from

[4] This of course only measures translucency with reference to those rays which affect the blue-print paper.

dry house air. Bits of the lower epidermis were peeled from the under surface of each kind of leaf at about 2-minute intervals and instantly placed in absolute alcohol to fix the stomata.[5] The operation was repeated on another day with fresh sets of leaves. It was found that in less than six minutes the stomata of the dry-air leaves were most of them closed to less than half their initial width, while

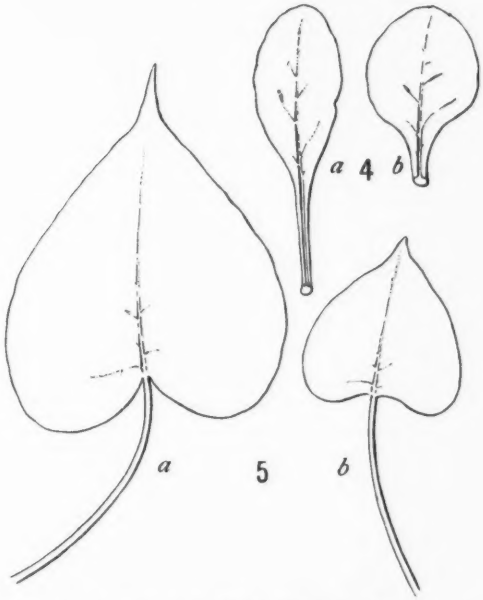


FIG. 4. Nicotiana leaves; *A*, moist-air form; *B*, dry-air form. ×½.—FIG. 5. Ipomoea leaves; *A*, moist-air form; *B*, dry-air form. ×½.

those of the moist-air leaves were but little affected. In about 15 minutes most of the stomata of the dry-air leaves were tightly closed, while most of those of the moist-air leaves still remained open. Apparently the speedy wilting of the moist-air leaves is due to two causes, the insufficient closure of the stomata and the relatively high permeability of the general surface of the epidermis to moisture.

[5] LLOYD, F. E., The physiology of stomata. Publ. 82, Carnegie Institution of Washington. 1908.

A curious kind of quick adaptation to dry conditions may sometimes be noted. Young leaves of Ipomoea, grown in nearly saturated air, were found to wilt in air of less than 30 per cent. relative humidity in about two minutes, though the stem was cut off under water and kept immersed in water. After being left for some hours in a saturated atmosphere until the wilting had entirely disappeared, the shoots were left, with the cut ends in water, in an atmosphere of less than 30 per cent. relative humidity for 48 hours without showing any signs of wilting. More than 90 per cent. of the stomata were at this time found to be perfectly closed.

The relative transpiration rate in diffuse light of moist-air and dry-air leaves of nearly all the kinds of seedlings grown was carefully determined. Attempts to make use of very slender (and therefore quick-reading) burettes as potometers were not successful. It was found too difficult to attach the soft and readily crushed stems of young seedlings to the burettes in such a way as to be sure to obviate leakage. All losses by transpiration were therefore estimated by weighing the shoots and the tubes of water which contained them on a balance sensitive to 5^{mg}. The relative humidity of the air in which the transpiration took place was measured by the sling psychrometer (sometimes twice) during each experiment. As might have been expected, the inequality of transpiration was found to be greatest in the case of fully developed leaves, half-grown ones showing less, though notable, differences. The values given below are for the ratio M/D, in which M is the transpiration of the moist-air leaf and D the transpiration of the dry-air leaf.

In discussing the results above given, it should be noted that a considerable range of values in the ratios obtained is almost unavoidable. In the first place we have to reckon with the great variability of transpiration in individuals of the same species grown under identical conditions. F. HABERLANDT[6] found in the case of rye plants that the transpiration per day varied (in round numbers) from 2 to 7^{gm} per square decimeter for different individuals. Also, if the transpiration were allowed to take place in a nearly saturated atmosphere (to prevent sudden wilting), the leaves would be under condi-

[6] HABERLANDT, F., Wissensch.-prakt. Untersuchungen auf dem Gebiete des Pflanzenbaues **2**:146. Wien. 1877.

tions abnormal for the kinds of plants studied. If the atmosphere were to be made very dry, the leaves grown in very damp air would wilt inside of five minutes or less and die in a comparatively short time. In some cases it was found best to determine the transpiration of readily wilted leaves for a period of fifteen minutes and compare

TRANSPIRATION RATIOS

Kind of leaf	Rel. humid. during trans. period	Ratio M/D
Phaseolus	25	2.2
Phaseolus	63	2.5
Phaseolus	64	3.2
Lupinus	26	4.0
Lupinus	about 43	8.2
Lupinus	about 38	10.0
Lupinus	variable, probably over 40	1.9*
Mirabilis	36	3.9
Mirabilis	29	4.8
Ipomoea	26	7.4
Salvia	34	6.6
Salvia	..†	8.9
Sinapis	28	3.5
Cucumis	24	3.9*
Cucumis	34	9.3
Nicotiana	about 50	3.1

* Young leaves, only half grown or less.

† The moist-air leaves transpired on May 12 in air of 28 per cent. relative humidity, and the dry-air ones on May 13 in air of 34 per cent. relative humidity.

this with the (calculated) fifteen-minute loss of the dry-air leaf of the same species, allowed to transpire for one or two hours. *Oxalis corniculata* from saturated air became wholly wilted inside of one minute, on being removed from the glass case, so its transpiration ratio could not be determined. It would be interesting to compare the relative transpiration of the two kinds of leaves in extremely dry air minute by minute, but weighings on a balance delicate enough for this purpose could not be made with sufficient rapidity.

The conditions as regards relative humidity were intentionally varied a good deal, in order to show whether the transpiration ratios follow closely the changes in humidity. It is evident that in Phaseolus and Lupinus they do not.

While no experiments were made with a view of measuring the absolute rates of transpiration of the plants studied, all under the same conditions of temperature and humidity, it may be worth

while to give the values obtained for moist-air leaves of some of them.

TRANSPIRATION OF 100 SQ. CM. OF LEAF IN AN HOUR

Plant	Temperature °C	Rel. humid. per cent.	Transpiration in milligrams
Cucumis.....	20	34	1485
Lupinus.....	21.67	43	3596
Nicotiana.....	21.11	50 or less	1950
Phaseolus.....	26.11	25	1647
Sinapis.....	22.22	28	2135

Summarizing the results obtained from the transpiration measurements,[7] it may be said that:

1. As a result of being grown in a highly humid atmosphere, all the plants studied acquire a much greater than normal capacity for transpiration in a moderately dry atmosphere.

2. Different families and different genera of the same family vary greatly in their capacity to acquire by such culture a tendency to extremely rapid transpiration.

3. The transpiration ratios, for the same species, become notably greater as the leaf becomes fully developed.

4. The transpiration ratios are not necessarily greater when the relative humidity of the air, during the period when transpiration is measured, is very low than when it has a medium value.

CAMBRIDGE, MASS.

[7] Not nearly all of these results have been tabulated in the preceding pages.

A REMARKABLE AMANITA[1]

GEORGE F. ATKINSON

(WITH EIGHT FIGURES)

During the autumn of 1908 I received from Mrs. VIRGINIA GARLAND BALLEN, of Brookdale, Santa Cruz Co., Cal., a number of specimens of an Amanita which presents several remarkable peculiarities in its development and environic relations. For several years Mrs. BALLEN has observed this Amanita and has made a careful field study of the more salient features of its development. This account of the fungus is based on fresh specimens and photographs which she has sent me, and upon her notes and descriptions, which show a remarkable appreciation on her part of the important morphological characters, as well as of important features of development.

This plant grows in the mountain forests of California. It is among the largest species of Amanita, the cap being 10 to 22^{cm} in diameter, one of the larger ones, according to Mrs. BALLEN, being sufficient for a meal. It thus rivals in size the royal Amanita of Europe, which it surpasses in robustness, though not possessing its rich orange-yellow color, and not attaining the height of the larger specimens of that species. It is interesting to note that the stocky character of this plant with its short stem is probably an expression of one of its environic and seasonal relations. It occurs in the high Sierras and in the Coast Range. Probably the entire summer season is needed for the growth and extension of the mycelium in the forest mold, so that the huge fruit bodies are developed in late autumn and early spring. While we have as yet no information bearing on the time of origin of the fundament of the fruit bodies, it is likely that all of them are formed during the summer and late autumn, and that the second crop, which appears early in the spring, is composed of plants which have lived through the winter in a partially developed condition. The autumn crop ceases about the last of December, while the spring crop begins about the middle of March.

[1] Contribution from the Department of Botany, Cornell University, No. 135.

In the high Sierras, where it is colder, the plant is well protected from frost injury, since it rarely if ever appears above the carpet of leaves covering the forest floor. Here it grows about the pines and firs. It has here almost become a subterranean fungus, a remarkable

FIG. 1.—Partly expanded plant, showing calyptra of volva closely adhering to the pileus, the veil with the floccose remnants of the fundamental tissue between it and the stem, and the limb of the volva at base of stem.

thing for an Amanita. Thus it is difficult to find, the only evidence of its presence being the mounds of conifer needles which the hidden plants raise above them. Uncovering these and removing the plant there is a large cone-shaped hole in the soil made by the pressure of the very thick stem and cap. They are often found in bitter cold

FIG. 2.—Three plants showing circumscissile dehiscence of the volva; the plant at the left with the delicate veil torn and (in front) the inner collar of the volva.

weather, when the ground is covered with snow, but are so well protected by the covering of needles and snow that they are perfectly fresh and uninjured, while a few hours' exposure to the air results in their being frozen. In the Coast Range they are smaller and not so

FIG. 3.—Partly expanded plant, showing veil attached at apex of stem and supported in a divergent position by the mass of loose cottony remnants of the fundamental tissue lying between the veil and stem.

bright-colored, and are found around the madroñas, chestnuts, oaks, pines, and spruces. Mrs. BALLEN has never found them around the redwoods. The spring crop is also paler than the autumn crop. In the mountains about Brookdale, Santa Cruz Co., they appear above the ground.

The pileus is a maize-yellow in its bright-colored forms and varies to a pale straw color or Naples yellow (R.) in the vernal forms. The gills are at first white and later become tinged with the same color. The stem and inner veil or annulus are also tinged with pale straw

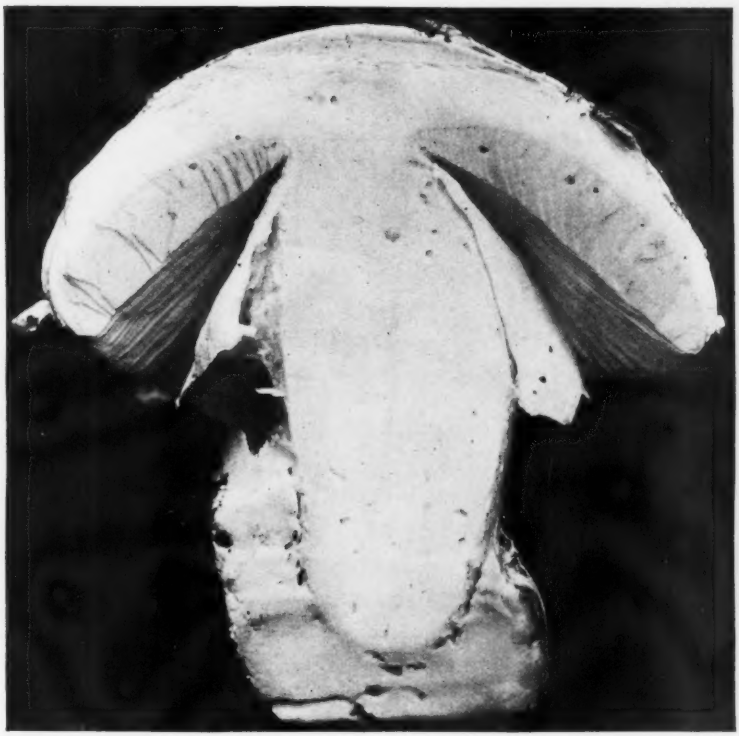


FIG. 4.—Section of plant showing pendent veil and loose cottony fundamental tissue between it and the stem.

color. The volva is thick, stout, and white, though in age it becomes more or less soiled and tinged with yellowish brown. The pileus is broadly rounded in the young plants, becoming broadly convex to plane, or in old plants the margin may become elevated, thus giving the pileus a depressed appearance.

Very little of the surface of the pileus is visible, since all except a narrow marginal portion is covered with the calyptra of the volva, which forms a thick, white, tough skin or covering, closely and tightly fitting the cuticle of the pileus. In cutting through the calyptra and pileus the line of junction can be seen, and in fresh plants this line of division is brought out distinctly because of the pale-yellow cuticle of the pileus. This calyptra, covering the larger part of the pileus like

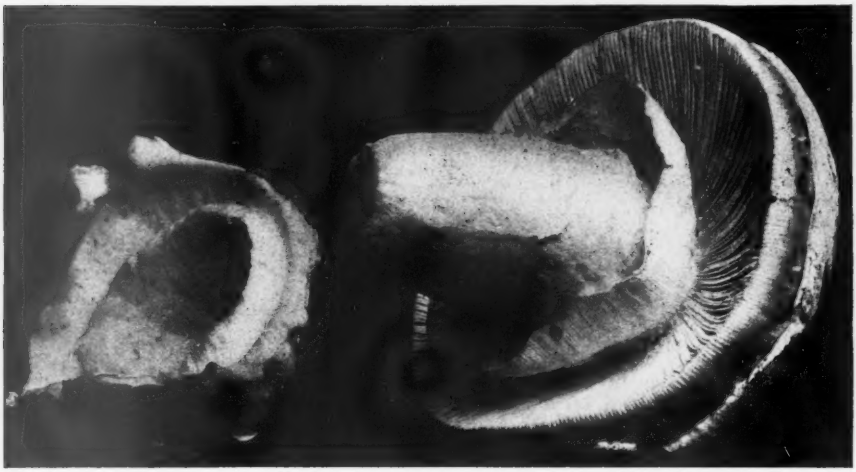


FIG. 5.—The stem separating from the volva; note inner collar of the volva, striate margin of the pileus, and very distinct thick calyptra.

a closely fitting cap, is often unbroken; but in large, well-expanded plants, it is often cracked into irregular large areas, as in *fig. 6*, showing the pileus between.

The inner veil is very thin and fragile, and disappears soon after the opening of the plant. When the plant is expanded the annulus is attached to the extreme upper end of the stem at the point of junction of the gills and stem, for the gills are adnexed, as in some other species of Amanita, and the stem is not readily separable from the pileus. The plant is very fleshy, is often attacked by larvae, and readily decays, so that transport of mature or nearly mature specimens is difficult.

In the button stage they sometimes carry and keep well for several days.

The inner veil is slightly connected with the edges of the gills and thus the expansion of the pileus produces a tension which tears the veil from the surface of the stem, with which it is also connected by

FIG. 6.—Surface of pileus, showing calyptra torn into large patches, which remain tightly adherent to the pileus.

remnants of the fundamental tissue. This tissue, lying between the veil and the stem, is very loose and floccose, so that it is torn into a delicate cottony mass, which often supports the veil in a divergent position as it hangs from the apex of the stem (*figs. 3, 4*). The veil itself is very delicate in texture, and Mrs. BALLEN says that it "seems to melt away" soon after the expansion of the plant. This indicates that it is not well differentiated from the fundamental tissue. In

buttons which were shipped to me, and which opened in transit or after reaching here, this inner veil did not separate from the stem, but remained as fundamental tissue clothing the stem (*fig. 7*, where the outline of the cortex of the stem is shown within).

The stem is stout and comparatively short. The volva is circumscissile, but the lower half, which remains attached to the base of the stem, is large, with an ample, stout, free limb forming a large sac-like structure resembling that of the Amanitas with apical dehiscence, though the edge is more even. Within the basal portion of the volva and surrounding the stem there is often present a narrow collar or secondary sheath, the origin and nature of which, to my knowledge, have never been carefully described in any Amanita, for it is usually overlooked.

This inner collar or secondary sheath I have studied carefully in *Amanita caesarea* of Europe, while studying the higher fungi in the Jura Mountains of France, from specimens collected at Besançon and Arbois, in September, 1905. PLOWRIGHT[2] has called attention to a similar inner collar in specimens of *Amanitopsis spadicea*, and proposed to employ it in separating this species from *A. livida*, the two being usually brought together under this name, but he offered no suggestion as to its significance or origin. I have observed it and studied its origin also in *Amanitopsis livida* Richon & Roze and do not think that much specific importance can be attached to it, since it varies so in strength in different specimens and is often so obscure when it remains, as it sometimes does, closely applied against the base of the stem. Great credit, however, is due to Mrs. BALLEN for having made such careful observations on the presence and nature of this interesting structure in the California Amanita, the more so since there is no published description of such a structure, and her observations, though later than mine on *Amanita caesarea* and *Amanitopsis livida*, were entirely independent of them, and made before she had called my attention to the existence of this species.

Longitudinal sections of the young plants when in the more advanced "egg" stage show all of the principal parts well formed. The pileus and stem when cut or bruised often turn a pale straw

[2] Trans. Brit. Mycol. Soc. **1897–8**:40. See ATKINSON, Mushrooms, edible, poisonous, etc. 75. 1st ed. 1900, Ithaca. 2d ed. 1901, Ithaca, and 1903, New York.

FIG. 7.—Plants photographed after transit from California to Ithaca, N. Y., showing dehiscence; middle plant in section, showing very distinctly the thickness of the calyptra; inner veil remaining attached to the stem and continuous below with the tissue that forms the collar on the inside of the volva, indicating that all of the tissue which lies between the stem and the gills is fundamental tissue.

yellow on exposure of the cut surface to the air. In such sections of young plants therefore the pileus is clearly marked off from the surrounding volva, and the wall of the stem is likewise marked off distinctly from the surrounding fundamental tissue. The gills are also well outlined. The slightly convex outline of their edge does not permit them to lie against the surface of the stem, and their lower or outer ends curve away from it in the young stage. This space is filled with fundamental tissue, and as the plant expands it is left free from

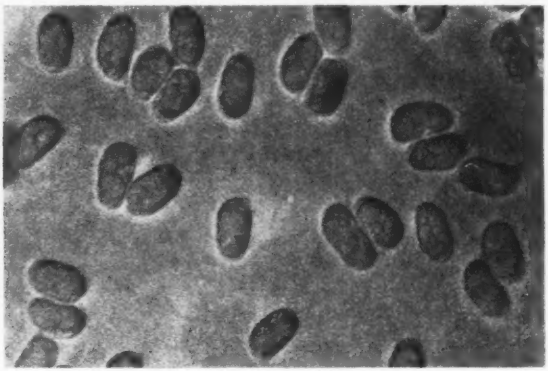


FIG. 8.—Photomicrograph of spores with Zeiss ocular 18, objective 3mm; object 370mm from plate-holder.

the stem and gills, but attached to the inner side of the base of the volva as a collar around the stem. When the plants become quite mature or old, there are tissue changes at the base of the stem inside of this collar which permits the stem to be very easily separated from the volva. By this time the free limb of the volva has recurved more or less, leaving the volva in the shape of a saucer with a recurved edge, and an inner collar. At this stage, if one takes hold of the cap to lift the plant, the stem is freed from the volva cup, leaving this saucer-shaped structure in the ground. *Fig. 5* is from a photograph of this stage, showing this saucer-like structure of the volva with its inner collar, and the freed stem at one side. In dry weather this separation of the stem from the volva does not take place.

I have proposed the name *Amanita calyptroderma* for this plant,

because the calyptra of the volva fits like a skin over the center of the pileus. Although a technical description has been published elsewhere,[3] it may be well to add a diagnosis here.

AMANITA CALYPTRODERMA Atkinson & Ballen.[4]—Plants 10–15^{cm} high, pileus 10–22^{cm} broad, stem 2–4^{cm} stout. Pileus maize-yellow to pale chrome-yellow, gills white, then pale maize to cream color, annulus and stem pale maize to cream color, volva white. Pileus stout, fleshy, convex to expanded and even depressed in age, margin striate, slightly viscid when moist, larger part of pileus covered with the tough thick calyptra of the volva which fits closely like a skin, the margin free, while in age in the larger plants the calyptra of the volva is cracked into rather large areas by the expansion of the pileus. Gills broad, adnexed, edge more or less floccose. Basidia 4-spored. Spores oval to elliptical, smooth, coarsely granular, 8–12×7–8 μ. Annulus very thin, membranaceous, superior, hanging from the extreme apex of the stem, soon disappearing. Stem hollow, with loose cottony threads, even in the smaller plants, tapering upward in the larger ones, or smaller at base, surface floccose. Volva white, thick, circumscissile, in dehiscence the upper part remaining on the center of the pileus, lower portion of limb very prominent, 2–4^{cm} long, sometimes appressed on the stem, but usually distinctly divergent and in age recurved, often with a distinct inner collar near the base, in age the stem often separating from the volva, leaving the latter as a saucer-shaped structure with its inner collar in the ground.—Mountain forests, California, in late autumn and early spring, *Mrs. Virginia Garland Ballen.* Herb., Cornell Univ., no. 22620.

[3] Science N. S. **29**:944. 1909.

[4] Closely related to *Amanita calyptrata* Peck, Bull. Torr. Bot. Club **27**:14. 1900, but differs in color and other characters.

UNDESCRIBED PLANTS FROM GUATEMALA AND OTHER CENTRAL AMERICAN REPUBLICS. XXXII[1]

JOHN DONNELL SMITH

Pithecolobium (§SAMANEA Benth.; Ser. *Carnosae* Benth.) **catenatum** Donn. Sm.—Folia ampla, pinnis unijugis, foliolis 3–5-jugis obovato-oblongis vel -ellipticis obtuse cuspidatis basi acutis, stipulis uti glandulae interpetiolulares obsoletis. Pedunculi axillares longissimi. Legumen lineare longissimum moniliforme polyspermum bivalve, loculamentis atque seminibus ellipsoideis.

Frutex, ramis petiolis pedunculis ferrugineo-puberulis. Petiolus communis 4–8^{cm} longus, pinnarum erecto-patentium rhachi 12–22^{cm} longa, foliolis chartaceis praeter costam utrinque puberulam glabris subtus pallidioribus in eodem jugo inaequalibus per paria deorsum decrescentibus, supremis 11–16^{cm} longis 5–7.5^{cm} latis, infimis 3–9^{cm} longis 2–4.5^{cm} latis, nervis lateralibus utrinque 6–7, venulis subtus minutissime reticulatis, petiolulis 2–3^{mm} longis. Pedunculi 8–18^{cm} longi, floribus sessilibus. Legumina crasse coriacea rubiginoso-subvelutina addito stipite 12–22^{mm} longo 24–26^{cm} longa epulposa demum dehiscentia inter semina arcte constricta, loculamentis 15–17^{mm} longis 9–11^{mm} crassis leviter compressis, isthmo infimo interdum 12–14^{mm} longo, ceteris 2–4^{mm} longis, seminibus 11–12 circiter 13–15^{mm} longis 8–10^{mm} latis atrocoloribus, hilo subapicali.—Florum tantum reliquiae visae. Ad *P. sophorocarpum* Benth. legumine semine embryone accedens foliis longe distat.

In silvis profundis ad praedium *Suerre* vocatum, Llanuras de Santa Clara, Comarca de Limón, Costa Rica, alt. 300^{m}, Febr. 1896, *John Donnell Smith*, n. 6479 ex Pl. Guat. etc. quas ed. Donn. Sm.

Appunia guatemalensis Donn. Sm.—Glabra. Stipulae breviter vaginantes bicuspidatae. Folia subsessilia magna elliptico- vel obovato-oblonga utrinque acuminata. Capitulum singulum pauci- et laxi-florum, bracteis ovario paulo longioribus glandulis 1–3 cuspidatis. Calyx campanulatus truncatus basi glanduligerus quam corolla octies brevior.

Frutex. Stipulae coriaceae acuminato-triangulares 3^{mm} longae, cuspidibus minutis. Folia subcoriacea utraque pagina nitentia 13–16^{cm} longa medio vel paulo supra medium 5–7^{cm} lata, omnia opposita, nervis lateralibus utrinque 5–6, petiolis 2–3^{mm} longis. Pedunculi axillares 3.5–4^{cm} longi, capitulo circiter 7-floro absque corollis 5–6^{mm} longo atque lato, bracteis acuminato-ovatis 1.5^{mm}

[1] Continued from BOT. GAZETTE **47**: 262. 1909.

longis, floribus heterogoneis (brevistylis solum visis). Calycis 2^{mm} longi in sicco nigricantis tubus hemisphaericus limbum aequans, glandulis linearibus paucis. Corolla 16^{mm} longa ad 2^{mm} supra basin staminigera. Antherae subsessiles 3^{mm} longae. Discus 0.5^{mm} altus. Ovarium 1^{mm} longum, stylo uti stigma pyramidale 1^{mm} longo. Bacca ignota.

In silva prope pagam maritimam *Livingston*, Depart. Livingston, Guatemala, Jun. 1906, *H. von Tuerckheim* (n. II. 1230).

Palicourea (§CROCOTHYRSUS Griseb.; Ser. *Croceae* Muell. Arg.) **leucantha** Donn. Sm.—Glabra. Stipulae vaginam amplam laxam truncatam subaequantes. Folia elliptico-oblonga utrinque acuminata. Thyrsus elongatus, axibus angulosis, bracteis bracteolisque majusculis. Calycis limbus alte partitus ovario 2–4-plo longior. Corolla alba ad $\frac{1}{4}$ altitudinis paleaceo-annuligera.

Internodia obtuse tetragona. Stipulae late sejunctae lineari-lanceolatae $4–5^{mm}$ longae. Folia subtus minute puberula $14–17^{cm}$ longa medio $4–7^{cm}$ lata, petiolis $1.5–3^{cm}$ longis. Thyrsus saepius foliis reductis fultus $13–18^{cm}$ longus supra basin $5–7^{cm}$ latus, ramis infimis arrectis $5–6^{cm}$ longis, bracteis bracteolisque lineari-lanceolatis $4–9^{mm}$ longis, cymis dichotomis, pedicellis $3–9^{mm}$ longis. Calycis lobi inaequales oblongo-ovati $2–4^{mm}$ longi trinervi. Corolla cylindrica computatis lobis 2^{mm} longis $15–16^{mm}$ longa margine virescens paleis niveis annuligera ad $\frac{2}{3}$ altitudinis staminigera. Antherae medio affixae 2^{mm} longae filamenta aequantes apice exsertae. Discus hemisphericus 1.5^{mm} altus. Ovarium cylindricum $1–1.5^{mm}$ longum atque crassum biloculare, stylo 7^{mm} longo, lobis 1.5^{mm} longis. Bacca deficit.—*P. mexicanae* Benth. affinis.

In silva montana ad viam inter Cobán et Tactic, Depart. Alta Verapaz, Guatemala, alt. 1800^{m}, Mart. 1903, *H. von Tuerckheim*, n. 8400 ex Pl. Guat. etc. quas ed. Donn. Sm.—In monte prope Cobán, Depart. Alta Verapaz, Guatemala, alt. 1650^{m}, Jun. 1908, *H. von Tuerckheim* (n. II. 2282).

Parathesis microcalyx Donn. Sm.—Folia lanceolato-obovata cuspidato-acuminata in petiolum attenuata integra supra glabra subtus glabrescentia. Panicula terminalis foliis superata. Calyx brevis, lobis deltoideis tubum aequantibus. Corolla staminibus bis longior. Ovarium apice pubescens totum post anthesin calyce aequilongo arcte cinctum depresso-globosum.

Folia recentiora subtus cum ramulis petiolis panicula floribus ferrugineo-pubescentia, provectiora glabra erga lucem inspecta punctulis et lineis pellucida, saltem superiora (solum visa) $9–12.5^{cm}$ longa $3.5–4^{cm}$ lata, petiolis $1–1.5^{cm}$ longis. Panicula $6–7^{cm}$ longa, floribus ad apicem versus ramorum secundariorum corymbosis, pedicellis minute lineari-bracteolatis $1.5–3^{mm}$ longis. Calyx 1^{mm} longus immaculatus. Corollae tubus 0.5^{mm} longus, laciniae lineari-lanceolatae 3^{mm}

longae acutae lineato-maculatae intus glabrae. Antherae ovatae 1^{mm} longae area dorsali atra deltoidea epunctatae filamentis bis longiores. Ovarium corolla jam delapsa 1^{mm} longum paulo latius quam longius, stylo 2.5^{mm} longo. Fructus desideratur.—*P. serrulatae* Mez proxima.

In fruticetis secus rivulum ad fundum *La Colombiana* dictum, Llanuras de Santa Clara, Comarca de Limón, Costa Rica, alt. 200^{m}, Jun. 1899, *H. Pittier*, n. 7591 ex Pl. Guat. etc. quas ed. Donn. Sm. (n. 13410 herb. nat. Cost.).

Gonolobus (§MONOSTEMMA K. Schum.) **leianthus** Donn. Sm.—Folia longe petiolata sparsim pilosiuscula ovato-oblonga acuminata sinu profundo rotundato cordata. Pedunculi biflori et pedicelli graciles, floribus glabris inter maximos. Segmenta corollina lanceolato-oblonga parum reticulata calycinis ovatis sesquilongiora. Corona tenuiter annularis subintegra gynostegio brevissimo adnata.

Frutex volubilis, ramis petiolisque patenter pilosis vel glabrescentibus, pedunculis pedicellisque glabris. Folia $9–12^{cm}$ longa $3.5–5^{cm}$ lata supra paene glabra subtus setulis minimis aspersa, petiolis $6–8^{cm}$ longis. Pedunculi $2–4^{cm}$ longi, pedicellis inaequalibus $3–5^{cm}$ longis, floribus 5^{cm}-diametralibus. Calycis segmenta paene sejuncta late imbricata herbacea 13^{mm} longa 5^{mm} lata acuminata. Corollae alte fidae segmenta 2^{cm} longa $7–9^{mm}$ lata acute elongata carnulosa in sicco badia erga lucem inspecta reticulata. Corona callis contiguis minutis multidenticulata mediantibus carinis tenuibus gynostegio connexa annulo membranaceo pubescente corollae adnato comitata. Gynostegium vix 1^{mm} altum 6^{mm}-diametrale.—*G. macrantho* Kunze proximus.

Cubilquitz, Depart. Alta Verapaz, Guatemala, alt. 350^{m}, Oct. 1901, *H. von Tuerckheim*, n. 8243 ex Pl. Guat. etc. quas. ed. Donn. Sm.

Trichostelma oblongifolium Donn. Sm.—Folia lanceolato-oblonga cuspidato-acuminata basi acuta vel obtusiuscula. Cymae sessiles. Segmenta corollina calycinis lanceolatis bis longiora ovato-lanceolata cymbiformia apice cucullato recurva. Corona exterior parce longeque ciliata, interior breviter cupularis vix lobata. Gynostegium breve appendicula paulo longius.

Suffruticosum volubile patenter pilosum. Folia discoloria utrinque pilis bulbosis aspersa $8–11^{cm}$ longa medio $3–5^{cm}$ lata, nervis subtus fusco-villosis, petiolis $1–2^{cm}$ longis. Pedicelli 3–5-fastigiati $1.5–3.5^{cm}$ longi, floribus extus hirsutis. Calycis partiti segmenta 4^{mm} longa reflexa sinubus uniglandulosa. Corolla nervosa 10^{mm} longa alte fissa. Corona exterior annularis hyalina, interior carnulosa corollae semiadnata a gynostegio libera anguste undulato-lobata margine extus lineari-rugosa. Appendicula a gynostegio pendula oblongo-bilobata 1.5^{mm} longa lobis divaricatis 3^{mm} lata. Pollinia pendula oblongo-elliptica caudiculis paulo longiora. Folliculi desunt.—A specie hactenus unica, *T. ciliato* Baill. (*Fimbristemma calycosa* Donn. Sm.), foliis atque floribus optime distinctum.

In fruticetis ad Panzal, Depart. Baja Verapaz, Guatemala, alt. 1000^{m}, Apr. 1907, *H. von Tuerckheim* (n. II. 1747).

Solanum (§ LEIODENDRA Dun.) **Rovirosanum** Donn. Sm.—Folia gemina parum inaequimagna elliptica vel obovato-elliptica bis longiora quam latiora in Sectione maxima sursum in angulum acutum vel obtusum desinentia in petiolum brevem plus minus attenuata, nervis lateralibus utrinsecus 6–7 ad axillas nudis. Pedicelli cymoso-fasciculati numerosi graciles, floriferi cernui, fructiferi erecti.

Frutex omnibus in partibus glaber. Folia pergamentacea concoloria nitida 19–30^{cm} longa 9–14.5^{cm} lata, altero circiter quinta parte minore, petiolis 8–18^{mm} longis. Pedunculi 10–24^{mm} longi nonnunquam furcati, pedicellis floriferis 6^{mm} longis, fructiferis 11^{mm} longis. Calyx obpyramidalis 2.5^{mm} longus, lobis tubo bis brevioribus rotundatis calloso-apiculatis. Corollae tubus 1^{mm} longus, laciniae lanceolatae 6–7^{mm} longae. Antherae conniventes oblongae 3^{mm} longae 1^{mm} latae nigricantes ad apicem luteum poris anticis amplis ellipticis dehiscentes, filamentis complanatis 1^{mm} longis. Ovarium ovoideum, stylo 5^{mm} longo. Bacca nondum satis matura calyce accrescente cincta globosa 7^{mm}-diametralis nigra.

Cubilquitz, Depart. Alta Verapaz, Guatemala, alt. 350^{m}, Aug. 1904, *H. von Tuerckheim*, n. 8716 ex Pl. Guat. etc. quas ed. Donn. Sm.; Jul. 1907, *H. von Tuerckheim* (n. II, 1888).—Eandem plantam collegit *José N. Rovirosa* in Mexico ad Mayito, Estado de Tabasco, Jul. 1889, et sub numero 544 distribuit.

Athenaea cernua Donn. Sm.—Glandulari-puberula. Folia glabrescentia plerumque solitaria ovata cuspidato-acuminata basi cuneata vel rotundata. Pedunculi axillares vel dichotomales solitarii, flore atque fructu cernuis. Calycis lobi elongato-triangulares sub anthesi tubo paulo longiores. Corollae limbus campanulatus triente lobatus, lobi deltoidei. Bacca coccinea.

Herbacea, ramis dichotomis sulcatis et petiolis glandulari-puberulis. Folia membranacea punctulata nervis et margine puberula 4–7.5^{cm} longa 2.5–4^{cm} lata integra interdum gemina, altero consimili triente minore, petiolis 1.5–3^{cm} longis. Pedunculi 2.5–3.2^{cm} longi subglabri, floribus 7^{mm} longis. Calyx glandulari-puberulus 3.5^{mm} longus, lobis sub anthesi 2^{mm} longis. Corollae luteae tubus cylindricus 1^{mm} longus, limbus abrupte ampliatus basi staminigerus, lobi 2–2.5^{mm} longi ciliolati. Antherae ovales 2^{mm} longae 1^{mm} latae filamentis subaequilongae. Ovarium ovoideum 1.5^{mm} longum, stylo 3.5^{mm} longo. Bacca globosa 8^{mm}-diametralis calycis aucti lobis 3.5^{mm} longis obvelata, seminibus fuscis scrobiculatis.

In silva ad praedium *Sasís*, Depart. Alta Verapaz, Guatemala, alt. 900^{m}, Maj. 1908, *H. von Tuerckheim* (n. II. 2245).

Brachistus ceratocalycius Donn. Sm.—Glabrescens. Folia lanceolata e medio utrinque acuteque angustata plerumque solitaria,

floralia gemina homomorpha subaequimagna. Pedunculi singuli vel 2–4-ni. Calyx medio infra marginem truncatam scariosam tuberculis 10 appendiculatus. Corolla infundibularis paulo ultra medium lobata. Antherae ellipticae filamentis altero tanto longiores.

Frutex, ramulis novellis furfuraceis. Folia 7–10^{cm} longa 1.7–2.5^{cm} lata supra primum puberula mox utrinque glabra, nervis lateralibus utrinsecus 5–6, venis transversis parallelis remotis parum manifestis, petiolis 5–12^{mm} longis et pedunculis calycibusque puberulis. Pedunculi 15–31^{mm} longi erecti. Calyx hemisphaericus 3.5^{mm} altus, margine scariosa 1^{mm} lata, tuberculis squarrosis subconicis. Corolla violacea (cl. repertor in scheda), 16–17^{mm} longa in alabastro griseo-pubescens, lobis lanceolatis ad apicem versus et ad margines pubescentibus. Antherae 5^{mm} longae 2.5^{mm} latae apiculatae margine exteriore dehiscentes. Ovarium ovoideum 2.5^{mm} longum in stylum aequilongum attenuatum. Bacca ignota.

In silva montana prope Cobán, Depart. Alta Verapaz, Guatemala, alt. 1600^{m}, Jan. 1908, *H. von Tuerckheim* (n. II. 2060).

Ruellia (§ DIPTERACANTHUS Baill.) **pygmaea** Donn. Sm.—Folia approximata minima oblongo-ovata acuminata basi acuta integra supra paleaceo-pilosa subtus nervis ferrugineo-strigillosa. Flores ad axillas oppositas foliorum superiorum subsessiles, bracteis linearibus calyce paulo longioribus corolla 5–6-plo brevioribus. Capsula puberula 4-sperma infra medium contracta et compressa.

Caules e rhizomate longe repente foliis abortivis munito passim ascendentes 6–8^{cm} longi simplices et petioli ferrugineo-strigillosi. Folia internodiis longiora superne imbricantia 13–25^{mm} longa 7–10^{mm} lata supra pilis longis articulatis aspersa utrinque lineolata, nervis lateralibus utrinsecus 4, petiolis 2–3^{mm} longis. Bracteae 4–5^{mm} longae paleaceo-pilosae. Calycis puberuli tubus 1.5^{mm} altus, segmenta linearia 2–2.5^{mm} longa. Corolla extus puberula 24^{mm} longa supra basin cylindricam 8^{mm} longam sensim et aequaliter ampliata faucibus 5^{mm} lata, lobis late rotundatis 3^{mm} longis. Stamina bene inclusa, antheris 2^{mm} longis. Capsula oblongo-ellipsoidea 8–9^{mm} longa acuminata sulcata, parte solida 4^{mm} longa, seminibus orbiculatis 2^{mm}-diametralibus margine cano-pubescentibus.—*R. humifusae* Hemsl. proxima.

Hacoc prope Cubilquitz, Depart. Alta Verapaz, Guatemala, alt. 600^{m}, Maj. 1904, *H. von Tuerckheim*, n. 8725 ex Pl. Guat. etc. quas ed. Donn. Sm.

Ruellia (§ PHYSIRUELLIA Lindau; Ser. *Eglandulosae*. Lindau) **guatemalensis** Donn. Sm.—Folia glabra ovata vel lanceolato-ovata acuminata basi angustata vel rotundata margine undulata. Flores subsessiles 1–4-ni axillares vel in cymis axillaribus terminales et dichotomales, cymis folia superantibus, axibus elongatis, bracteis

longissimis. Corolla usque ad medium cylindrica tum ventricoso-infundibularis.

Frutex, ramis obtuse tetragonis minute cystolithigeris, angulis et nodis puberulis. Folia chartacea utrinque praesertim supra lineolata 9.5–10.5^{cm} longa 3.5–4^{cm} lata, vel superiora magis ovata 5^{cm} longa 2.5^{cm} lata, nervis lateralibus utrinsecus 4–5, petiolis puberulis canaliculatibus amplexicaulibus 10–18^{mm} longis. Cymae nondum satis evolutae addito pedunculo 5–8^{cm} longo 10–14^{cm} longae puberulae parce furcatae pauciflorae, axibus erecto-patentibus 1.5–3.5^{cm} longis, bracteis linearibus 2–3^{cm} longis, bracteolis lanceolatis 2^{mm} longis. Calycis tubus 2^{mm} longus, segmenta linearia 7^{mm} longa. Corollae tubus totus 3^{cm} longus, pars cylindrica 1.5^{mm}-diametralis, lobi obovato-orbiculares 8^{mm} longi emarginati. Stamina inclusa, filamentis per paria leviter connatis, majoribus 8^{mm} longis minores dimidio superantibus, antheris 2.5^{mm} longis. Discus 0.5^{mm} altus. Ovarium glabrum oblongo-lineare 5^{mm} longum 12-ovulatum triente contractum et vacuum, stylo puberulo 31^{mm} longo. Capsula matura ignota.

Ad praedium *Concepción* vocatum, Depart. Escuintla, Guatemala, alt. 400^{m}, Apr. 1890, *John Donnell Smith*, n. 2115 ex Pl. Guat. etc. quas ed. Donn. Sm. (Sub *Ruellia*. sp. olim distributa.)—Ad ripas fluminis Ocosito prope pagum *Caballo Blanco*, Depart. Retalhuleo, Guatemala, alt. 80^{m}, Apr. 1892, *John Donnell Smith*, n. 2692 ex Pl. Guat. etc. quas ed. Donn. Sm.

Pseuderanthemum verapazense Donn. Sm.—Folia lanceolato-oblonga in acumen obtusum angustata basi acuta praeter costam subtus viscidulo-puberulam glabra. Spica terminalis simplex vel ramis binis aucta bracteis foliaceis lineari-oblongis fulta, bracteolis triangulari-linearibus calyce bis brevioribus, floribus singulis subsessilibus.

Caules e rhizomate longe repente hinc illinc erecti subsimplices 10–25^{cm} longi teretes bifariam viscido-pubescentes. Folia lineolata 5–7^{cm} longa 18–20^{mm} lata, petiolis pubescentibus 3–4^{mm} longis. Spica puberula 3–7^{cm} longa, ramis 2–3^{cm} longis, bracteis 12^{mm} longis 3^{mm} latis, bracteolis 1.5^{mm} longis et floribus puberulis. Pedicellus 0.5^{mm} longus. Calycis segmenta linearia acute attenuata 3–3.5^{mm} longa. Corollae laete azureae (cl. repertor in schedula), tubus 16^{mm} longus triente superiore paulo ampliatus ceterum vix 0.5^{mm}-diametralis, lobi elliptici 7.5^{mm} longi 4^{mm} lati. Stamina ad 6^{mm} infra fauces affixa, filamentis 2^{mm} longis, antherarum loculis oblongis 1.5^{mm} longis aequalibus basi acutis, staminodiis 1^{mm} longis. Ovarium puberulum 4-ovulatum, stylo 16^{mm} longo bilobo. Capsula ignota.—*P. hispidulo* Radlk. proximum.

In silvis montanis ad Yaxcabnal, Cubilquitz, Depart. Alta Verapaz, Guatemala, alt. 320^{m}, Mart. 1902, *H. von Tuerckheim*, n. 8258 ex Pl. Guat. etc. quas ed. Donn. Sm.

Dicliptera (§SPHENOSTEGIA Nees) **podocephala** Donn. Sm.—Folia breviter petiolata ovato-lanceolata subsensim acuminata basi

angustata. Pedunculi axillares 1–3-ni elongati monocephali, captulis lineari-bracteatis, involucris 3–8 uni- vel bi-floris, phyllis involucralibus apice rotundato cuspidatis, bracteolis 4 calyce bis longioribus. Corolla paulo exserta.

Fruticulosa 1–1.5-metralis diffusa, ramis obtuse sex-angularibus uti petioli pedunculi involucra lineolatis et puberulis. Folia membranacea glabra cystolithis striolata 8.5–12.5^{cm} longa 3.5–4.5^{cm} lata, petiolis 13–17^{mm} longis. Capitula omnia pedunculata, pedunculis 1–9.5^{cm} longis in axillis superioribus singulis, in inferioribus binis vel ternis inaequalibus. Bracteae capitula semicircularia fulcientes binae 4–7^{mm} longae, involucris plerumque 5, exterioribus decrescentibus, phyllis obovatis basi cuneatis pergameneis nervosis reticulatis per paria inaequimagnis, majore 11–14^{mm} longo 8–9^{mm} lato in statu sicco colorato, altero quarta parte minore viridi, bracteolis lanceolato-linearibus 8^{mm} longis, flore altero abortivo vel deficiente. Calycis laciniae setaceae cum bracteolis puberulae. Corolla 14^{mm} longa, limbo pubescente. Antherarum loculi inaequialte affixi. Stylus 12^{mm} longus. Capsula pubescens ovoidea 5^{mm} longa apiculata disperma, seminibus puberulis 2.5^{mm}-diametralibus.

In pratis humedis ad praedium *Atirro* vocatum, Prov. Cartago, Costa Rica, alt. 600^{m}, Apr. 1896, *John Donnell Smith*, n. 6685 ex Pl. Guat. etc. quas ed. Donn. Sm.

Justicia (§ DIANTHERA Lindau) **Tuerkheimiana** Donn. Sm.—Pilosa eglandulosa. Folia oblongo-ovata apice obtusiuscula basi cuneata sparse paleaceo-pilosa. Spica terminalis pedunculata folia superiora subaequans, bracteis laxe imbricatis lanceolato-ellipticis. Calycis segmenta acuta. Corollae tubus tenuissimus.

Herba procumbens diffusa ad genicula radicans 23–30^{cm} longa, ramis obtuse tetragonis et petiolis et pedunculo patenter pilosis, glandulis obsoletis. Folia ejusdem paris parum inaequalia 23–38^{mm} longa 12–19^{mm} lata lineolata, nervis lateralibus utrinsecus 4–5, petiolis 4–10^{mm} longis. Pedunculus circiter 11^{mm} longus. Spica 24–27^{mm} longa, bracteis 5–9^{mm} longis 2–3^{mm} latis utrinque acutis deorsum autem longius angustatis sparse pilosis ciliatis, bracteolis lineari-lanceolatis 3^{mm} longis. Calycis segmenta lineari 4^{mm} longa, postico filiformi 2^{mm} longo. Corollae tubus 4^{mm} longus vix 0.5^{mm}-diametralis, labia extus puberula 2^{mm} longa. Filamenta 1.5^{mm} longa, antherarum loculis ovalibus inaequalibus breviter disjunctis. Ovarium 1^{mm} altum 4-ovulatum, stylo 5^{mm} longo. Capsula ignota.—*J. Schenckianae* Lindau arcte affinis.

Ad fissuras saxorum, Cubilquitz, Depart. Alta Verapaz, Guatemala, alt. 350^{m}, Jun. 1903, *H. von Tuerckheim*, n. 8726 ex Pl. Guat. etc. quas ed. Donn. Sm.

BALTIMORE, MD.

BRIEFER ARTICLES

NEW NORMAL APPLIANCES FOR USE IN PLANT PHYSIOLOGY. V[1]

(WITH TWO FIGURES)

In the preceding articles I have described some ten new pieces of apparatus designed for educational work in plant physiology; accounts of three more are given below, while others are to follow. They are called normal appliances because they are intended to represent the optimum resultant, the harmonic optimum, as it were, between accuracy of results and convenience of use, while at the same time they can always be bought from the stock of a supply company. As in the case of the other pieces these are to be manufactured and sold by the Bausch & Lomb Optical Company of Rochester, N. Y.

X. Space markers

For some purposes, especially in the study of growth, it is necessary to mark off a structure into regular divisions, either areas as in the case of young leaves, or lengths as in roots, stems, or petioles. It is not difficult to improvise appliances for accomplishing these ends, but as yet no tools are available for effecting them quickly, accurately, and conveniently, while at the same time always ready for use. This need, I think, the two little instruments here described will supply.

First, for marking lengthwise, the instrument is a wheel, the rim of which is a rubber stamp having raised cross-lines 2^{mm} apart. It revolves freely but evenly on an axle held in the end of a handle, and when suitably inked by the method described below, it may be run rapidly over long structures such as roots, marking them with narrow black cross-lines equally spaced, precisely as shown at the bottom of *fig. 1*.

Second, for marking areas, the instrument is a disc, likewise a rubber stamp, having raised lines in the form of squares 2^{mm} on a side. It works by means of a scissors-frame against a cushion disc covered with soft felt and provided with a radial slot to admit the petiole of a peltate leaf. When the marking disc is inked and pressed firmly against a leaf held on the cushion disc, it marks a network of even fine black lines like the sample shown in *fig. 1*. The marking disc is hinged to its supporting arm in a

[1] Continued from BOT. GAZETTE **43**:279. April 1907.

way to permit the disc to settle evenly upon the leaf surface no matter what the thickness of the leaf.

Both instruments may be inked from an ordinary rubber-stamp pad, and the black record kind gives good results. Better, however, is a simple

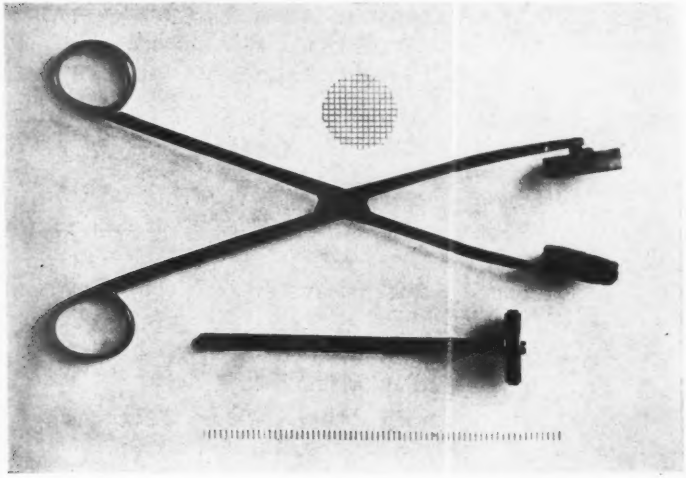


FIG. 1.—Space markers. ×½.

pad made from one fold of thin close cotton cloth attached by thread to an ordinary glass slide, and inked when needed by a mixture of three parts Higgins' waterproof India ink and one part glycerin.

XI. Demonstration auxograph

Among the most important of the topics which all teachers desire to demonstrate in general botanical courses is growth, and this can be shown to complete satisfaction only through use of a recording instrument. Many recording auxanometers, or auxographs, have been described, but as yet no practical instrument for educational purposes is obtainable by purchase. The essentials of a good demonstration instrument, aside from easy applicability to its work and durability, are reasonable accuracy, ready portability, visibility of record from some distance, and clear exhibition of its mechanism and principle. These ends, I believe, are well met in the instrument here described and illustrated (*fig. 2*).

It consists essentially of four parts: support-stand, recording cylinder, magnifying wheel, and plant-support. The support-stand is of rigid

though thin steel, and is provided with convenient handles, leveling screws, and suitable holes for the two upright rods. The recording cylinder,

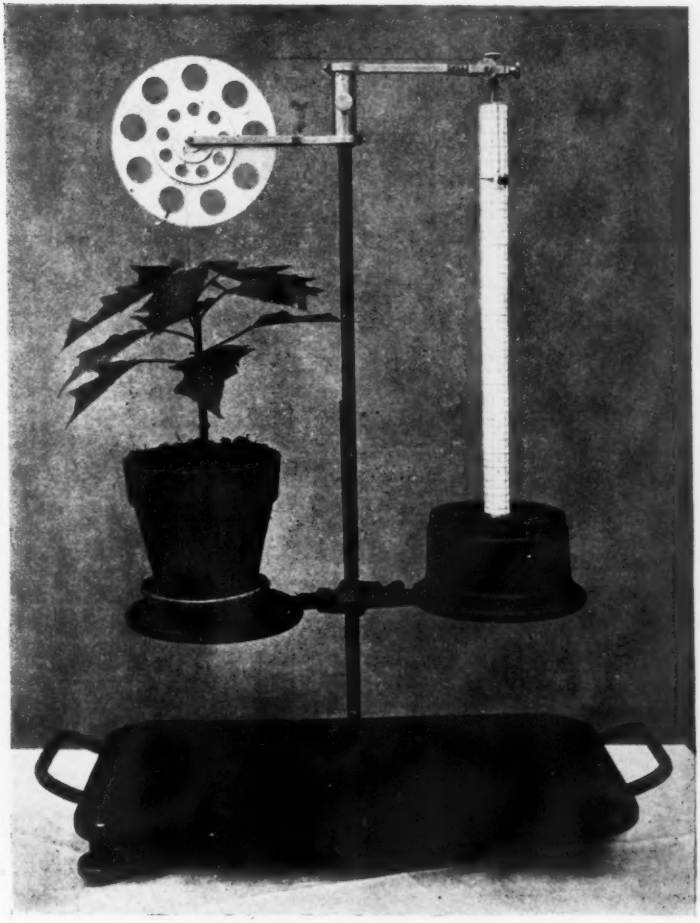


FIG. 2.—Demonstration auxograph. ×¼.

supported and guided at the top by a screw pivot, turns once an hour, and is of such circumference that each millimeter of a millimeter record paper represents one minute. It is carried by a clock which is supported at such

a height that it may be wound and regulated from beneath without disturbing the record. The magnifying wheel, really four concentric wheels combined, allows three degrees of magnification, two, four, and eight times the actual growth. It is made of aluminum, moves on a very sensitive axle, has suitable openings for attachment of threads, and is provided with a clamp for holding it immovable while adjustment of threads and the like is being made. The tip of the plant is brought into action with the wheel by means of a fine thread in the usual way; but in order that this thread may be kept as short as possible, a plant support, adjustable for height, is provided on a separate rod, thus permitting the tip of the plant to be kept close to the magnifying wheel, though, of course, care must be taken to prevent the danger of shading, and hence of phototropic bendings. This adjustable support, however, has another very important use which will be mentioned below. The thread from the large wheel passes over a pulley to the pen carrier, which slides on a fine guide wire and has sufficient weight to turn the wheels in proportion as the growth of the plant permits the small wheel to turn. The pen is of glass, drawn to a capillary point and bent so as to rest at right angles to the paper. It is filled with chronograph ink, and, as the plant grows and the cylinder turns, it traces a fine spiral line down the cylinder, crossing any given vertical line once an hour. When this pen has reached the bottom of the cylinder, one has only to put on a new cylinder or record paper, turn the large wheel backward until the pen is drawn to its top, close the clamp to hold the wheel immovable, lower the plant support until the thread from the plant becomes again taut, loosen the clamp to allow the tensions to adjust themselves, and then the record is resumed; and this procedure can be repeated until the end of the experiment without any need for ever touching the threads. This is the other advantage, above mentioned, of the adjustable plant-support. One should never draw up the pen by lowering the plant support, as there is a constant temptation to do, since this brings an unnatural strain upon the plant tip. All parts of the instrument, even to the arms carrying magnifying wheel and pulley, are adjustable, so the instrument may be made to work smoothly under any conditions. While designed primarily for making records of growth, it can be used for any measurements involving movement, e. g., the rise of water in a tube.

The weak point of all auxographs lies in the threads, which will alter length hygroscopically and thus introduce error into the record, despite any known treatment with wax, oil, rubber, etc. These alterations may be minimized by treating the threads with wax, and by keeping them as short as possible, for which reason they should be made only long enough to

allow the turning of the wheels, with no extra turns around the latter. The error, of course, is greatest from the thread attached to the plant, since its alterations of length are magnified in the record. Not only should this thread be kept short, but I think a glass filament could advantageously be substituted for all of its length except the loop at the plant and the partial turn around the wheel. The results of these errors can also be relatively minimized by using plants of the most rapid and vigorous growth, such as the flower-stalks of bulbous plants.—W. F. GANONG, *Smith College, Northampton, Mass.*

CURRENT LITERATURE

BOOK REVIEWS

Anisophylly

A monograph on this subject has been prepared by FIGDOR,[1] *privat-docent* in plant physiology in the University of Vienna. It is inspired by WIESNER, the distinguished physiologist of that university, and is dedicated to him. Naturally enough it is dominated by his views, and is interspersed with quotations from his writings. FIGDOR has gathered together what is at present known regarding anisophylly and has presented (critically, he says) the subject from both the morphological and the physiological point of view. In space, at least, the former predominates; and it must be confessed that the physiology is too obscure yet to be very satisfactory.

In the first section (36 pp.) the author defines the term, states the history of the phenomenon, and describes, as various sorts, incomplete, exorbitant, complete, lateral, habital, secondary, and false anisophylly. The second section (67 pp.) describes all the cases of anisophylly observed, in the systematic order from lycopods to composites, including cases of anisocotyly. The third section (55 pp.) discusses briefly the branching and symmetry of anisophyllous plants. The fourth and most interesting section (55 pp.) treats the causes of anisophylly—light, gravity, precipitation, nutrition, transpiration, exotrophy, and correlations. This fourth section would have been much shorter had FIGDOR discussed only causation; he intends to enumerate experimental work on all recorded cases, including new observations of his own. He has overlooked, however, the beautiful demonstration of DORETY[2] that gravity is the cause of anisocotyly in Ceratozomia; nor among the anisophyllous gymnosperms does he mention this and other cases in cycads.

The general conclusion is that anisophylly, which is very much more general than is commonly thought, cannot be said to be due in nature directly to the specific single causes to which experiments often point; but rather to the complex of factors, external and internal, which act on the primordia of the leaves. Primarily, therefore, the position of these is important, and that is conditioned by the orientation of the axes which bear them, with all its complex causation. But anisophylly may be in part phylogenetic, as well as ontogenetic; and here we

[1] FIGDOR, W., Die Erscheinung der Anisophyllie: eine morphologisch-physiologische Studie. 8vo. pp. viii + 175. *figs.* 23. *pls.* 7. Franz Deuticke: Leipzig und Wien. 1909.

[2] DORETY, HELEN A., The seedling of Ceratozamia. BOT. GAZETTE **46**:305. 1908.

meet factors of whose value we are ignorant. That ignorance needs emphasis. To say—"anisophylly is to be looked upon as a special case of anisomorphy, by which we understand, with WIESNER who proposed this term, that fundamental property of living substance in consequence of which the different organs (in our case the foliage leaves) have the power, each according to its position toward the horizontal or toward the parent axis, to assume different typical forms"—is merely to cloak ignorance with pedantry.—C. R. B.

Desert vegetation

A very fitting celebration of the fifth anniversary of the establishment of the Desert Laboratory was the publication of a treatise on North American deserts by Dr. MACDOUGAL, the director of the department of botanical research of the Carnegie Institution.[3] Had there been any doubt concerning the wisdom of establishing the Desert Laboratory, it must have been long ago dispelled by the number of valuable contributions emanating from Tucson. The contribution here considered includes some of the matter that made up the body of the first report on our desert region by COVILLE and MACDOUGAL in 1903 (Publication 6), but the great amount of new material, based on subsequent explorations and on the investigations at Tucson, made imperative the publication of a general treatise of this sort. An account is given first of the earlier investigations of the institution and the development of the department of botanical research, especial attention being directed to problems of long continuance, such as the study of the revegetation of the Salton Basin and experiments on acclimatization. Nearly half of the work is devoted to a general account of the various desert regions of North America, including the various Mexican deserts, the northern sage-brush deserts, the Mohave desert and Death Valley, the Sonoran and Colorado deserts. Then follows a sketch of the geological features of the region about Tucson, by Professor W. P. BLAKE, territorial geologist of Arizona; herein is contained an account of the soils, including the *caliche*, an interesting calcareous formation arising through deposition from waters percolating upward. An interesting sketch is given of the seasonal changes in the aspect of the vegetation about Tucson. The early winter rains stimulate the development of a number of winter perennials and annuals. In the spring and early summer the aspect is controlled by more xerophytic spinose and succulent forms, notably the cacti. The humid midsummer, like the winter, is characterized by a number of forms stimulated to development by the greater moisture. The treatise closes with a consideration of temperatures of plants in the desert (it being suggested that the great difference between air and soil temperatures is likely to be of significance), the water relations of desert plants, soil relations of desert plants, conditions contributory to deserts, and some general remarks on the formation and extent of deserts and the influence of the desert on life. This treatise will be a *sine qua non* for all ecological workers, since it brings together what is known concerning our deserts, taking

[3] MACDOUGAL, D. T., Botanical features of North American deserts. Carnegie Institution of Washington, Publication 99. 1908.

account of collateral information as well as the researches at the Desert Laboratory.—HENRY C. COWLES.

Animal galls

A prodigious amount of work is represented by the two ponderous volumes of HOUARD, devoted to the galls, produced by animals, which have been found upon European plants, including those of the Mediterranean basin.[4] Few botanists, we imagine, are aware of the extent of what now really ranks as a special branch of biological science, cecidology, which has its own journal, *Marcellia*, and is awakening the interest of both botanists and entomologists.

In this monumental work HOUARD describes 6239 zoocecidia, produced by 1466 species of animals, on 2299 species of plants. Of the animal gall-producers the most important are the Insecta, of the families Curculionidae (Coleoptera), Cynipidae (Hymenoptera), Cecidomyidae and Muscidae (Diptera), Aphididae (Hemiptera), and the Arachnida, of the family Eriophyidae. The Nematodes furnish 16 cecidogena, of the family Anguillulidae; while even Copepoda and Rotifera are represented by one species each. Of the plants 68 are cryptogams, 35 gymnosperms, 173 monocotyls, and 2053 dicotyls.

A large number of the galls are illustrated by original figures and some copies, both external and sectional views being given when necessary to show structure. The part of the plant deformed is indicated; the gall is described tersely, with compact and inconspicuous bibliographical notations; the specific name of the animal responsible for the deformity is given when known, otherwise the best data available; and finally an indication of the geographical distribution is added. There is a full bibliography, arranged alphabetically by authors; an index to the animals named, preceded by a tabular view of the genera, classified by families and orders; and an index of the plants by genera and species.

It is not often one sees a scientific work involving such multifarious detail planned so carefully and carried out so consistently and successfully. Herein the publishers doubtless deserve praise for active cooperation. It would be difficult to find a flaw in either plan or execution.

Since no extensive studies on the cecidia of this country have been made, these volumes, the most thorough, comprehensive, and accurate that have yet appeared in any country, will doubtless serve for many years in the preliminary work that needs to be done on our own galls. They must certainly be most useful, and it is to be hoped that with such a guide, more of our younger biologists will take up the study with vigor.—C. R. B.

A Darwin memorial volume

Among the numerous publications in commemoration of the centenary of the birth of CHARLES DARWIN and of the fiftieth anniversary of the publication of

[4] HOUARD, C., Les zoocécidies des plantes d'Europe et du bassin de la Méditerranée. 2 vols. 8vo. pp. 1248. *figs. 1365. pl. 2. portraits 4.* Paris: A. Hermann & Fils. 1909. 45 *fr.*

the *Origin of species*, no one seems more appropriate and satisfactory than the volume issued by the Cambridge Philosophical Society and the Syndics of the University Press.[5] It consists of twenty-eight essays written by those who are most competent to present the various appropriate topics. The result is to illustrate the far-reaching influence of DARWIN's work and also the present attitude of investigators toward Darwinism. Some of the essayists have restricted themselves to DARWIN's own work; while others have outlined the progress of more recent research, which has been the direct outcome of his work. Two photographs of DARWIN are reproduced, one made in 1854, and the other in 1880; while a reproduced etching gives a most interesting view of the study at Down. To review such a collection of essays briefly is impossible, but the subjects and the authors will indicate the general contents to those interested in evolutionary doctrine. Ten of the twenty-eight essays are of interest to botanists.

The series most appropriately begins with an introductory letter by Sir JOSEPH D. HOOKER, for forty years the intimate friend and correspondent of DARWIN. The ten essays of botanical interest are as follows: "Darwin's predecessors," by J. ARTHUR THOMSON (15 pp.); "The selection theory," by AUGUST WEISMANN (48 pp.); "Variation," by HUGO DE VRIES (19 pp.); "Heredity and variation in modern lights," by W. BATESON (17 pp.); "The minute structure of cells in relation to heredity," by EDUARD STRASBURGER (10 pp.); "The palaeontological record. II. Plants," by D. H. SCOTT (23 pp.); "The influence of environment on the forms of plants," by GEORG KLEBS (24 pp.); "Geographical distribution of plants," by W. T. THISELTON-DYER (21 pp.); "Darwin's work on the movement of plants," by FRANCIS DARWIN (16 pp.); "The biology of flowers," by K. GOEBEL (23 pp.)

All of these essays address themselves primarily to the intelligent public rather than to investigators, and therefore they are in a sense popular statements and not contributions to knowledge. In spite of this, they are very interesting to investigators, for personal and recent points of view are in evidence throughout, and the whole group of related topics is brought together in clear and compact form.—J. M C.

MINOR NOTICES

Recent publications from the National Herbarium.—A. S. HITCHCOCK (Contr. U. S. Nat. Herb. 12: 183–258. 1909) has issued a "Catalogue of the grasses of Cuba." The work is based primarily on material in the herbarium of the Experiment Station at Santiago de las Vegas, Cuba. Sixty-six genera are recorded and to these are referred 225 species of which 10 are indicated as new; one new genus (*Reimarochloa*) is proposed. More than one-half (36) of the genera here listed are represented by single species. The author gives carefully prepared keys leading to the genus and species and also cites numerous exsiccatae, thus greatly

[5] Darwin and modern science. Essays edited by A. C. SEWARD. 8vo. pp. xvii + 590. Cambridge: The University Press. 1909. $5.00.

enhancing the practical value of the publication.—J. N. ROSE (*ibid.* 259–302) has published the sixth paper in his "Studies of Mexican and Central American plants." About 75 species are described as new, and several transfers have been made. Three new genera (*Pelozia*, *Pseudolopezia*, and *Jehlia*) of the Onagraceae are briefly characterized. The text is supplemented by numerous illustrations.—P. C. STANDLEY (*ibid.* 303–389. *pls. 28–43*) publishes an interesting systematic treatment of the Allioniaceae, dealing chiefly with those of the United States. The author recognizes 16 genera, describes about 50 species and some 20 so-called sub-species as new to science; three of the genera enumerated are new, namely *Anulocaulis*, *Commicarpus*, and *Hesperonia*. Through an apparent oversight the genus Commicarpus either has been omitted from the key to the genera or confused with Senkenbergia.—N. L. BRITTON and J. N. ROSE (*ibid.* 391, 392. *pls. 44, 45*) propose a new genus (*Thompsonella*) of the Crassulaceae; the genus is represented by two Mexican species. The type of the genus is *Echeveria minutiflora* Rose.—J. N. ROSE (*ibid.* 393–409. *pls. 46–59*) describes 10 new species of flowering plants chiefly from Mexico and the southwest, including also a new genus (*Conzattia*) of the Leguminosae, and makes critical notes on species previously published.—N. L. BRITTON and J. N. ROSE (*ibid.* 413–437. *pls. 61–76*), in an article entitled "The genus Cereus and its allies in North America," have recorded 24 genera, of which 15 are designated as new. Of the 131 species enumerated 12 are described as new, 77 form new combinations, and 19 are of doubtful generic relationship. The new genera proposed are as follows: *Acanthocereus*, *Bergerocactus*, *Heliocereus*, *Hylocereus*, *Lemaireocereus*, *Leptocereus*, *Lophocereus*, *Nyctocereus*, *Pachycereus*, *Peniocereus*, *Rathbunia*, *Selenicereus*, *Weberocereus*, *Werckleocereus*, and *Wilcoxia*.—J. N. ROSE (*ibid.* 439, 440. *pls. 77–81*) describes and illustrates 5 new species of Crassulaceae from Mexico.—J. M. COULTER and J. N. ROSE (*ibid.* 441–451. *pls. 82, 83*) have issued a "Supplement to the monograph of the North American Umbelliferae" in which the authors include descriptions of 6 new species; two new genera are also proposed, namely, *Ligusticella* and *Orumbella*.—W. R. MAXON (*ibid.* 411. *pl. 60*) describes and illustrates a new species of Asplenium from China; and (*ibid.* 13:1–43. *pls. 1–9.* 1909) in continuation of a series of articles begun in an earlier volume of this journal has published results of further studies of tropical American ferns. In this paper, the second of the series, the author describes 16 species of ferns and 2 species of Lycopodium from Mexico and Central America, and also presents a "Revision of the West Indian species of Polystichum" in which 19 species are recognized, 4 being hitherto undescribed.—J. M. GREENMAN.

A garden book.—A lover of flowers will find pleasure and inspiration in a charming book entitled *A little Maryland garden* by HELEN ASHE HAYS.[6] She writes in a most interesting and pleasantly intimate way of her experiences in starting a flower garden, of her successes and failures, and of the great satisfaction

[6] HAYS, HELEN ASHE, A little Maryland garden. 12 mo. pp.——. *pls. 8.* New York: G. P. Putnam's Sons. 1909. $1.75.

one derives from a garden which is *klein, aber mein*. The book is beautifully illustrated with eight halftones in color by ZULMA DE L. STEELE, and would be a pleasing gift book, as well as an excellent reference book for an amateur who may feel, with the author, that "at least it is better to have tried and failed, than not even to have made the attempt." The author, however, was evidently successful and shows an intimate knowledge of garden life. The nature sketches are pleasing, and the whole book is written in a very happy vein, to which its attractive form is appropriate.—MARY H. FROST.

Hymenomycetes of the Chicago region.—The Natural History Survey of the Chicago Academy of Sciences has begun the publication of a descriptive catalogue of the higher fungi of the Chicago area. The first part, containing the Hymenomycetes by MOFFATT, has just appeared.[7] It is well printed and the plates are halftones from excellent photographs. The keys to genera and species should make determination comparatively simple, but the key to genera would be far more convenient if the page numbers were inserted. The "Chicago area" means Cook and Dupage counties, with portions of Will County, Ill., and Lake County, Ind., including about 1800 square miles. From this area 371 species of Hymenomycetes are reported, representing 79 genera, the distribution by families being as follows: Agaricaceae, 46 gen., 211 spp.; Polyporaceae, 15 gen., 78 spp.; Hydnaceae, 5 gen., 25 spp.; Thelephoraceae, 8 gen., 41 spp.; Clavariaceae, 2 gen., 12 spp.; Tremellaceae, 3 gen., 4 spp.—J. M. C.

Indian woods and their uses.—The Imperial Forest Research Institute of India has begun the publication of a series of memoirs, the first number of which deals with Indian woods and their uses.[8] It is a bulky quarto volume of nearly 500 pages, dealing wih 554 species. This is only a fraction of the total number ot Indian woody species, which is said to be about 5000 and rather more than half of them trees. The first part contains a list of the purposes for which woods are employed and the woods used for each, while in the second part these woods are described. There is an index to English and trade names (9 pp.), and also a surprisingly extensive one (202 pp.) to vernacular names.—J. M. C.

The flora of central and southern Congo.—Another fascicle[9] of this important taxonomic work has been issued recently under the able editorship of Professor ÉM. DE WILDEMAN. The present fascicle contains a list of Mycetes prepared by the late Professor P. HENNINGS, also a list of fungi by H. and P. SYDOW; the Pteridophyta have been elaborated by Dr. H. CHRIST and the Embryophyta by Dr. DE WILDEMAN. Nearly one hundred new species and several varieties are

[7] MOFFATT, W. S., The higher fungi of the Chicago region. Part I. The Hymenomycetes. Chicago Acad. Sci. Nat. Hist. Surv. Bull. **7**:1–156. *pls. 1–24.* 1909.

[8] TROUP, R. S., Indian woods and their uses. Indian Forest Memoirs **1**: No. 1. 4to. pp. 273+ccxvii. 1909.

[9] DE WILDEMAN, ÉM., Flore du Bas- et du Moyen-Congo. Ann. Mus. Congo. Botanique, Sér. V. Tome iii. fasc. 1. pp. 147. *pls. 27.* Brussels. 1909.

here published, and the text is supplemented by twenty-seven full-page illustrations.—J. M. GREENMAN.

Handbook of deciduous trees.—The ninth part[10] of SCHNEIDER's *Handbook* (the fourth section of the second volume) has followed the preceding one[11] with great promptness. As already noted, it presents descriptions of the species of angiospermous trees, native or under cultivation in central Europe, and is illustrated freely. The present part begins with Tilia and ends with Rhododendron. —J. M. C.

NOTES FOR STUDENTS

Morphology of Tumboa.—Three years ago PEARSON published[12] the results of his investigation of Tumboa (Welwitschia) from material obtained in one day's collecting. A second expedition to Damaraland was made possible and material was collected during January and February of 1907, the results of the investigation of which are now published.[13] The additional stages thus secured have put our knowledge of this most interesting plant upon a fairly substantial basis, and PEARSON is to be thanked for his persistent enthusiasm in securing this difficult material. An outline of what seem to be the most significant new results is as follows:

The staminate and ovulate strobili are often produced in great profusion and their occurrence below the single pair of leaves is frequent. Pollination is mainly effected by a hemipterous insect (Odontopus), the pollen being received by a nectar drop on the top of the projecting micropylar tube. The pollen grains frequently germinate in the micropyle at some distance from the tip of the nucellus, the tube growing down through the fluid which fills the micropyle at the time of pollination. The generative cell passes into the tube, where its nucleus divides, the binucleate cell either remaining undivided or forming two male cells. The tube nucleus begins to break down before fertilization and eventually disappears.

The most critical and puzzling structure of Tumboa, however, is the embryo sac. Megaspores and embryo sacs are often present in the pith region of the axis of the ovulate strobilus, so that the cauline origin of the ovule is clear. A single megaspore mother cell is organized and a single megaspore functions. The female gametophyte begins with free nuclear division and no vacuolation, and successive simultaneous divisions occur until there are approximately 1024 free and crowded nuclei. Elongation of the sac then occurs, chiefly in its micropylar

---

[10] SCHNEIDER, C. K., Illustriertes Handbuch der Laubholzkunde. Neunte Lieferung (vierte Lieferung des zweiten Bandes). Imp. 8vo. pp. 367–496. *figs. 249–328.* Jena: Gustav Fischer. 1909. *M* 4.

[11] BOT. GAZETTE **47**:415. 1909.

[12] PEARSON, H. H. W., Some observations on *Welwitschia mirabilis* Hooker. Phil. Trans. Roy. Soc. London B **198**:265–304. *pls. 18–22.* 1906. Review in BOT. GAZETTE **42**:67. 1906.

[13] ———, Further observations on Welwitschia. Phil. Trans. Roy. Soc. London B **200**:331–402. *pls. 22–30.* 1909.

fourth, so that the outer nuclei are more widely separated than the rest. These more scattered nuclei are sexually functional, while the more crowded ones in the inner three-fourths of the sac give rise to the endosperm. Incomplete wall-formation occurs, dividing the sac into irregular and multinucleate compartments, those of the upper fourth usually containing not more than six nuclei, while those of the lower three-fourths contain twelve or more nuclei. The outer multinucleate cells develop tubular prolongations (prothallial tubes) into the nucellus, into which the nuclei and most of the cytoplasm pass. Occasionally these sexual nuclei fuse within the prothallial tube. In the multinucleate cells of the inner three-fourths of the sac the nuclei seldom divide, but all fuse, forming uninucleate cells. This endosperm, consisting of uninucleate cells whose nuclei are formed by the fusion of what the author regards as potential gametes, he calls a *trophophyte*, to distinugish it from both gametophyte and sporophyte, and says that it "differs fundamentally from the prothallus of the lower gymnosperms," a statement which will have to be amended in a way that will make the proposed name seem unnecessary.

When connection is established between the tip of a pollen tube and of a prothallial tube, "the leading female nucleus enters the generative cell within which fertilization occurs," which is certainly a remarkable performance.

In embryo-formation, the fertilized egg elongates to form a proembryonal tube, toward the tip of which the nucleus moves and divides, when a tip cell is cut off by an ingrowing wall, just as in Gnetum. The tubular cell of the proembryo continues to elongate, while the tip cell develops the embryo, which consists of about sixty cells when its tip reaches the endosperm.

The author enters into a somewhat extended discussion of the general bearings of the facts he has uncovered, a discussion which will be considered in another connection.—J. M. C.

Mechanism of photeolic movements.—LEPESCHKIN, whose investigations of turgor mechanisms have been already extensive and important, has added a study of the mechanism concerned in the so-called sleep movements of leaves, which he designates as photonastic.[14] (It seems to the reviewer much better to reserve the terms compounded of *-nastic* for the irreversible movements due to growth. As an equivalent of the cumbrous *Variationsbewegungen* eolic movements may be suggested. Long since[15] I proposed for the sleep movements the term photeolic movements, avoiding thus the false implications of sleep, nyctitropic, and photonastic.) Without referring to the divergent views of various authors on which his

---

[14] LEPESCHKIN, W. W., Zur Kenntnis des Mechanismus der photonastischen Variationsbewegungen und der Einwirkung des Beleuchtungswechsels auf die Plasmamembran. Beih. Bot. Centralbl. **24**:308–356. 1909. Preliminary paper: Zur Kenntnis des Variationsbewegungen. Ber. Deutsch. Bot. Gesells. **26a**:724–735. 1908.

[15] HEALD, F. D., Contribution to the comparative histology of pulvini and the resulting photeolic movements. BOT. GAZETTE **19**:480. 1894.

conclusions bear, an attempt is made here to state clearly and tersely LEPESCHKIN's conception of the various processes concerned in the movements by motor organs.

A change in illumination induces a change in the permeability of the plasma membranes for solutes; this results in an alteration of the turgor pressure, which of course alters the volume of the opposed halves of the motor organ, and alters it in the same fashion, though not at the same rate or to the same extent. Darkening reduces permeability, and consequently increases the turgor; lighting has the opposite effect. The result of the inequalities of these changes in turgor is a curvature of the pulvinus. After this has appeared, diffusion of the solutes begins toward the convex side, where the concentration is now lowest in consequence of the absorption of water in this half and its expulsion on the concave side; this leads to the restoration of the normal concentration of sap and a resultant heightening of turgor on the convex side, with a corresponding lowering of it on the other, thus intensifying the curvature. Alteration of permeability by changes of illumination is not peculiar to motor organs, but occurs also in epidermal cells of Tradescantia and in Spirogyra, where it is proportionally as great, but cannot have the same consequences.[16] Of the two movements ordinarily induced by change in illumination, the rise or fall of the leaf and the reverse, only the primary movement is produced as described; the reverse movement is rather of the nature of an after-effect of the primary curvature. Geotropic curvatures of the motor organs are explicable on the same principles. The physiological dorsiventrality of the motor organs is due to the normal direction of gravity. Plants which raise their leaves on darkening, have their photeolic movements intensified by being inverted, while those that drop their leaves have them reversed by inversion.—C. R. B.

Seedling structure of gymnosperms.—The third paper under this title, by HILL and FRAINE,[17] treats of the Ginkgoales and Cycadales, and contains the usual valuable coordination of scattered results. Under the three heads of cotyledons, transition region, and root, the following conclusions are reached:

Cotyledons.—The cotyledons, generally two in number, are hypogeal and are persistently imbedded in the gametophyte; they are frequently unequal and there is a marked tendency to form lobes, and in some cases there is a short basal tube; among Cycadales they are more or less closely fused by their ventral surfaces; stomata are generally present, secretory cells and canals are common, and the vascular bundles are mesarch or exarch in varying degrees; the number of bundles in each cotyledon varies from one to eight, in all cases being greater in the central region than near the base or tip.

Transition region.—The transition phenomena occur rapidly, so that most of the hypocotyl shows root structure; Ginkgo differs from the observed cycads in that it has a rotation of the protoxylem of the cotyledonary traces; in Ginkgo each cotyledonary bundle gives rise to two poles of the root (except in the case of

[16] See also TRÖNDLE, p. 318.

[17] HILL, T. G., AND FRAINE, E. DE, On the seedling structure of gymnosperms. III. Annals of Botany **23**:433–458. *pl. 30.* 1909.

three cotyledons, when the root is triarch); among cycads the cotyledonary bundles are not of equal value in the production of root structure, and even similarly situated bundles vary in the same species; among the cycads the cotyledonary bundles fuse with the plumular traces and ultimately form a central cylinder of variable structure.

Root.—In Ginkgo there may be an addition of protoxylem elements after the root structure has been organized; in Stangeria the primary root may branch dichotomously; after the initial root structure has been attained, the number of poles may be increased at lower levels.

The paper closes with a very useful table showing the variation in the number of bundles in the base of the cotyledons of the fourteen species discussed, and also the relation of this number to the number of poles in the root structure.—J. M. C.

Adaptation in fossil plants.—In his presidential address[18] at the anniversary meeting (May 24) of the Linnean Society, SCOTT took occasion to outline the evidence for adaptation from fossil plants, which naturally dealt chiefly with the anatomical structures of those ancient vascular plants which he has done so much to elucidate. No one is more competent to state the facts in reference to ancient plants, but the conclusions do not seem to be irresistible. In substance they are as follows: (1) at all known stages in the history of plants there has been a thoroughly efficient degree of adaptation to the conditions existing at each period; (2) the characters of plants always having been as highly adaptive as they are now, natural selection appears to afford the only key to evolution which we possess at present; (3) the paleontological record reveals only a relatively short section of the whole evolution of plants, during which there has not been any very marked advance in organization, except in cases where the conditions have become more complex, as illustrated by the floral adaptations of angiosperms; (4) the simple forms of the present flora are reduced rather than primitive, but such reduction may have set in often at a relatively early stage of evolution, and is therefore consistent with a considerable degree of antiquity in the reduced forms.

These broad statements, quite apart from their application to certain views of adaptation, contain much wholesome truth for those who imagine that the paleontological record, as we know it, represents a continuous succession of "higher and higher" plants, for it is becoming increasingly evident that very highly organized plants existed at the very beginning of our record.—J. M. C.

Morphology of Penaeaceae.—STEPHENS published a preliminary account[19] of his studies among the Penaeaceae which was noticed in this journal.[20] There has now appeared the full account with illustrations,[21] so that the morphological

[18] SCOTT, D. H., Presidential address before Linn. Soc., 1909. pp. 15.

[19] STEPHENS, E. L., A preliminary note on the embryo sac of certain Penaeaceae. Annals of Botany **22**:329. 1908.

[20] BOT. GAZETTE **45**:365. 1908.

[21] STEPHENS, E. L., The embryo sac and embryo of certain Penaeaceae. Annals of Botany **23**:363–378. *pls. 25, 26.* 1909.

features of this small shrubby group, restricted to the southwestern region of Cape Colony, are fairly before us. Three of the five genera were investigated (Sarcocolla, Penaea, and Brachysiphon), suitable material of the other two (Endonema and Glischrocolla) not being available.

The morphological characters of the three genera examined are the same, so that one account can serve for all. The megaspore mother cell produces four nuclei, usually tetrahedrally arranged, and these migrate to the periphery of the embryo sac, where each gives rise to a group of four nuclei. Three of the nuclei of each group are organized into cells which resemble an egg-apparatus, while the four remaining free nuclei fuse in the center of the sac to form the primary endosperm nucleus, which after fertilization forms a parietal layer of nuclei, walls appearing much later. The embryo has no suspensor, appearing first as a spherical mass of cells, which elongates as the tissues are differentiated and the growing points are organized.

This seems clearly an illustration of the formation of an embryo sac by the cooperation of four megaspores, in this case the product of each megaspore remaining remarkably distinct.—J. M. C.

Embryo sac of Pandanus.—A preliminary note[22] under this title has already been referred to in this journal.[23] The fuller account, with plates, has now been published.[24] Pandanus has long been regarded as a promising primitive monocotyledon, and its investigation is most timely. The general results are as follows: the archesporial cell (presumably solitary) cuts off a parietal cell which gives rise to several layers of cells separating the epidermis from the megaspore mother cell; the mother cell divides transversely into two daughter cells, the inner one of which directly produces the embryo sac, while the outer one divides anticlinally; the first division within the sac (the second reduction division) results in two polar nuclei; the micropylar nucleus divides, and there is no division of the daughter nuclei, nor is there usually any differentiation into egg and synergid; the antipodal nucleus gives rise to twelve nuclei, whether by simultaneous division or not was not determined; in the most advanced stages secured no nuclear fusion was observed, all fourteen nuclei remaining quite separate.

The author still maintains that the embryo sac of Pandanus is a more ancient type than the ordinary eight-nucleate sac of angiosperms, and that it represents a new type, "with its nearest analogue in Peperomia." It remains to investigate the fertilization stages of this interesting embryo sac, to determine whether the fourteen-nucleate condition really is the fertilization stage.—J. M. C.

---

[22] CAMPBELL, D. H., The embryo sac of Pandanus. Preliminary note. Annals of Botany **22**:330. 1908.

[23] BOT. GAZETTE **45**:364. 1908.

[24] CAMPBELL, D. H., The embryo sac of Pandanus. Bull. Torr. Bot. Club **36**:205–220. *pls. 16, 17*. 1909.

The new flora of Krakatau.—Under this title CAMPBELL[25] has published an interesting account of a visit to the island of Krakatau, which was "efficiently sterilized" in August 1883, the hot ashes and pumice completely covering the island to an average depth of 30^{m}. The nearest land is an island 19^{km} distant, on which the vegetation was largely destroyed; while Java and Sumatra are 35 and 45^{km} distant. TREUB visited the island in 1886 and 1897, and it was examined again in 1905 and 1906. By 1886, three years after the catastrophe, a considerable number of plants had been established, the ferns predominating in species (11) and individuals, while 9 species of seed plants were sparsely represented. The Cyanophyceae were also found to be of great importance as aids in the establishment of higher vegetation, the blackish slimy films of species of Oscillatoria coating the surface of the ashes. In 1897, while there were almost no trees, most of the island was covered by vegetation, 62 species of vascular plants being recorded (12 pteridophytes, 50 seed plants), and the ferns still predominating in the number of individuals. In the present flora 137 species have been recorded, representing all the principal groups; the ferns are no longer predominant; and the forest vegetation is rapidly encroaching toward the center of the island. There is a remarkable paucity of bryophytes, only two mosses and one Anthoceros having been recorded.—J. M. C.

Mechanism of anthers.—SCHNEIDER, having investigated the tulip carefully, objects[26] to the conclusions of STEINBRINCK that the rupture of anthers is due to the cohesion of the diminishing water with that in the cell walls. In this problem he would distinguish the mechanics of the first rupture, of the first recurvature of the valves, and of their subsequent rolling and unrolling. In Tulipa he finds the first rupture due to the pressure of the growing pollen mass—an explanation already more than a century old. He does not enlighten us as to the remaining processes; possibly they are treated in an earlier paper which we have not seen.[27]

To this paper STEINBRINCK replies at some length,[28] in the usual lively polemic style of our Teutonic friends. Though tulips were out of bloom before SCHNEIDER'S article came to his attention, his preserved material even furnishes some arguments, which are further supported by an examination of the behavior of a large number of plants of other genera. The only one in which STEINBRINCK is willing to admit that anything but cohesion mechanism plays a part, even in the first opening of the valves, is the rye. In this anther "another strong tissue tension must cooperate, because the broad cleft remains open when one throws the anther

[25] CAMPBELL, D. H., The new flora of Krakatau. Amer. Nat. **43**:449–460. 1909.

[26] SCHNEIDER, J. M., Zur ersten und zweiten Hauptfrage der Antherenmechanik. Ber. Deutsch. Bot. Gesells. **27**:196–201. 1909.

[27] ———, Der Oeffnungsmechanismus der Tulipanthere. Altstatten, 1908. (Inaugural Dissertation.)

[28] STEINBRINCK, C., Ueber den ersten Oeffnungsvorgang bei Antheren. Ber. Deutsch. Bot. Gesells. **27**:300–312. *figs.* 7. 1909.

at once into water." The first rupture in this case is an explosive one, which scatters some of the pollen, and cannot be due to the cause assigned by SCHNEIDER. —C. R. B.

Mesostrobus, a new genus of Carboniferous lycopods.—WATSON[29] has described the strobilus of a new lycopod from the Lower Coal Measures of Lancashire. It resembles Lepidostrobus, but the sporangium is only attached to the distal half of the horizontal portion of the sporophyll, and the somewhat larger ligule is set in a deep pit. A characteristic point of view is illustrated by the following quotation: "Lepidostrobus would be derived from a cone having sporophylls of this type" (*Bothrodendron mundum*, etc.) "on the adoption of an arboreal habit by the heterosporous lycopods, because radial elongation of the sporangium is the most economical way of increasing the number of spores produced, a necessity for a large tree. If this elongation takes place in the part of the sporophyll between the axis and the insertion of the sporangium, we arrive at a condition much like that of Spencerites, and from that condition we can pass through Mesostrobus to Lepidostrobus."—J. M. C.

Heating of leaves.—It has been known that the evolution of heat may be demonstrated in living plants by using seedlings and flowers, but leaves have not been considered favorable material for this experiment. MOLISCH has now shown[30] that in many cases 3–5^{kg} of leaves, placed in a basket and packed in "excelsior," show a rise in temperature amounting to 20–45° C. within 12–24 hours. The leaves are usually killed thereby, and after a fall a second rise of temperature begins, which may attain a maximum somewhat higher or lower than the first. The first evolution of heat he ascribes to the respiration of the leaves, while the second is due to the rapid development of microorganisms. The experiment is simple and worthy a place in the laboratory practice.—C. R. B.

Osmotic pressure and permeability.—TRÖNDLE records another example of what has been observed by others, namely, change in the permeability of the protoplast according to the conditions of lighting and temperature. His preliminary report[31] concerns the leaves of *Tilia cordata* and *Buxus sempervirens rotundifolia;* in the former both palisade and spongy parenchyma, in the latter only the palisade being investigated. He reports also the high values of 20–26A for the osmotic pressure as determined by plasmolysis. It is to be remembered that plasmolytic studies, such as these, in many of which NaCl was used, are of

[29] WATSON, D. M. S., On Mesostrobus, a new genus of lycopodiaceous cones from the Lower Coal Measures, with a note on the systematic position of Spencerites. Annals of Botany **23**:379–398. *pl. 27.* 1909.

[30] MOLISCH, H., Ueber hochgradige Selbsterwärmung lebender Laubblätter. Bot. Zeit. **66** :211–233. 1908.

[31] TRÖNDLE, A., Permeabilitätsänderung und osmotischer Druck in den assimilierender Zellen des Laubblättes. Ber. Deutsch. Bot. Gesells. **27**:71–78. 1909.

questionable validity in the light of OSTERHOUT's researches in this line.[32]—C. R. B.

Anatomy of the ovule of Myrica.—Miss KERSHAW[33] has investigated the ovule of *Myrica Gale*, and has discovered that in all of the morphological features it is an ordinary angiosperm, with its solitary megaspore mother cell, linear tetrad, eight-nucleate embryo sac, and porogamy. The following anatomical features, however, are worthy of mention: the nucellus is not only completely free from the single integument but is also distinctly stalked within it; vascular strands (eight or nine in number) traverse the integument, without branching, almost to the apex of the ovule. These two features of the ovule are usually regarded as primitive, belonging to the ancient gymnosperms rather than to angiosperms.—J. M. C.

Phototropism of roots.—LINSBAUER and VOUK, after overcoming many experimental difficulties, have found[34] that the roots of *Raphanus sativus* and *Sinapis alba*, which have been credited with being only negatively phototropic, react positively or negatively according to the intensity of the light. Roots of the former in moist air turn toward light of about 8 candles, while in water they are much less sensitive, no very certain curvatures being obtained until the light was increased to 400 c.p. Sinapis in water, on the contrary, gave the best positive response at 0.2 c.p., and decided negative curvatures at 0.64 c.p. These results support the MÜLLER-OLTMANNS theory of phototropism.—C. R. B.

Dispersal of seeds by ants.—WEISS[35] has concluded that the gorse (Ulex) and the broom (Sarothamnus) should be included among myrmecochorous plants, along with Chelidonium, Viola, etc. He finds that the seeds have a brightly colored caruncle containing oily food material and resembling in structure and contents the elaiosomes (of SERNANDER) of other myrmecochorous plants; that ants are particularly attracted by the oil-containing caruncle, and can and will carry about the seeds of gorse; and that the rectilinear distribution of gorse bushes along actual or disused paths or roadways is only paralleled by the distribution of such plants as the celandine along ant-runs.—J. M. C.

Anatomy of Gleichenia.—BOODLE and HILEY[36] have investigated the vascular structure of Gleichenia, a genus interesting on account of its protostelic species.

[32] BOT. GAZETTE **46**:53–55. 1908.

[33] KERSHAW, EDITH MAY, The structure and development of the ovule of *Myrica Gale*. Annals of Botany **23**:353–362. *pl. 24*. 1909.

[34] LINSBAUER, K., AND VOUK, V., Zur Kenntnis des Heliotropismus der Wurzeln. Ber. Deutsch. Bot. Gesells. **27**:151–156. 1909.

[35] WEISS, F. E., The dispersal of the seeds of the gorse and the broom by ants. New Phytol. **8**:81–89. 1909.

[36] BOODLE, L. A., AND HILEY, W. E., On the vascular structure of some species of Gleichenia. Annals of Botany **23**:419–432. *pl. 29*. 1909.

G. pectinata was especially studied, whose rhizome BOODLE[37] had discovered to be solenostelic. This has now been confirmed, solenostely with leaf gaps being found. It is concluded that Eugleichenia represents a series of reduction forms from the Mertensia type (represented by *G. flabellata*), and that Mertensia includes the most primitive species as well as the most advanced (*G. pectinata*), in which a solenostelic structure has been derived from a protostelic.—J. M. C.

Ovule of Julianiaceae.—Miss KERSHAW[38] sees in the integumental vascular strands and free nucleus of this recently established Mexican family a suggestion of relationship between Juliania and Juglans, and especially in the association of this structure in both genera with the outgrowth at the base of the ovule known as the obturator. The suggested connection with Anacardiaceae is confirmed by the integumental vascular strands of Mangifera, but in that genus there is no indication of an obturator.—J. M. C.

Chlorophyll in evergreens.—Miss CÄCILIE STEIN reports[39] that crude chlorophyll (i. e., all the pigments) increases in amount with the season, and from February to March far more than from March to May; from that time on it seems about constant. The chlorophyll proper increases likewise and decidedly more than the xanthophyll. This, she suggests, may be due to the conversion of the xanthophyll into chlorophyll; but KOHL's experiments strongly antagonize such an explanation.—C. R. B.

Stock and scion.—At a meeting of the Botanical Society of France last March GRIFFON discussed the results of his numerous experiments in grafting during 1908,[40] and declared that, whatever the plants employed (Solanaceae, Leguminosae, Compositae), and whether the graft was simple or mixed, there was no trace of asexual hybridization, but further confirmation of the specific independence of the stock and scion.—C. R. B.

An abnormal Funaria.—DIXON[41] describes a plant of *Funaria hygrometrica* from Tonduff having the perigonial leaves fringed by a double row of protuberant and more or less flask-shaped cells which are supposed to function as reservoirs of water supplementary to the paraphyses for keeping the antheridia well supplied. —C. R. B.

---

[37] BOODLE, L. A., On the anatomy of the Gleicheniaceae. Annals of Botany **15**:703. 1901.

[38] KERSHAW, E. M., Note on the relationship of the Julianiaceae. Annals of Botany **23**:336, 337. 1909.

[39] STEIN, CÄCILIE, Beiträge zur Kenntnis der Enstehung des Chlorophyllpigmentes in den Blättern immergrüner Koniferen. Oesterr. Bot. Zeits. **59**:231–245, 262–269. 1909.

[40] GRIFFON, E., Troisième série de recherches sur la greffe des plantes herbacées. Bull. Soc. Bot. France **56**:203–210. *pls. 3, 4.* 1909.

[41] DIXON, H. N., A remarkable form of *Funaria hygrometrica*. Bryologist **12**:49–51. *pl. 5.* 1909.